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- **ADVANCES IN INSTRUMENTATION, vol. 37, no. 3, 1982 NC,US, pages 1075-1085, YOSHIO FUKAI,E.A. 'GAS FLOW MEASUREMENT BY VORTEX FLOWMETER'**

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Description

[0001] The present invention relates to flow metering apparatus. More particularly, it relates to sensors for vortex flowmeters and to piezoresistive sensor assemblies and housings therefor.

[0002] It has been known for many years that vortices are developed in a fluid flowing past a non-streamlined obstruction. It also has been known that with certain arrangements that vortices are developed by alternately shedding at regular intervals from opposite edges of the obstruction to form corresponding rows of vortices. Such vortices establish a so-called von Karman "vortex street," which is a stable vortex formation consisting of two nearly-parallel rows of evenly-spaced vortices travelling with the flow stream.

[0003] In a von Karman vortex street, the vortices of one row are staggered relative to those of the other row by approximately one-half the distance between consecutive vortices in the same row. The spacing between successive vortices in each row is very nearly constant over a range of flow rates, so that the frequency of vortex formation is correspondingly proportional to the velocity of the fluid. Thus, by sensing the frequency of vortex formation it is possible to measure the fluid flow rate. Devices for that purpose are often referred to as vortex meters.

[0004] Various types of vortex meters have been available commercially for a number of years. Typically, these vortex meters comprise a vortex-shedding body mounted in a flow tube together with a sensor for detecting the frequency of vortex formation. Sensors used to detect the vortices often include diaphragms which fluctuate in response to alternating pressure variations generated by the vortices. For example, in U.S. Pat. No. 3,972,232 to Miller et al. and U.S. Pat. No. 4,220,046 to Sqourakes, pressure applied to the diaphragms is transferred to a piezoelectric sensor which then produces electrical signals responsive to differential pressure applied to the diaphragms. This differential pressure measurement is used, in turn, to measure the frequency of vortex formation and ultimately the fluid flow rate or velocity.

[0005] A limitation of this type of sensor is that it is capable of making only one measurement in a single process penetration, specifically, measuring differential pressure fluctuations used to compute the flow velocity. Additional instruments and process penetrations would be required in order to obtain additional measurement quantities, such as pressure or temperature. This increases the risk of releases of fugitive emissions and fluid loss and bears an increased cost for the purchase and installation of the additional instruments

[0006] Another disadvantage of additional process penetrations is the loss of accuracy in the measurements due to varying sampling points. Since the physical characteristics of the fluid changes within the flow, accurate measurements would require a common source point from which to sample within a single penetration.

[0007] US-A-3, 972, 232 discloses a flow-metering apparatus and method of determining characteristes of a process flow according to the preambles of claims 1 and 9, respectively. The present invention is characterized by the features of the characterizing portions of these claims.

[0008] Additional features are set out in the dependent claims.

[0009] European Application EP-A-0666 468 (which takes priority from U.S. Serial No. 08/192,237 and filed on 4th February 1994 in the name of Kalinoski, R.W.) filed on the same day as this application, also contains details of the sensor arrangements.

[0010] This invention results from the realization that accurate measurements of the physical characteristics of a fluid's flow can be made within a vortex flowmeter in a single process penetration from a common source point located directly within the stream of the fluid flow.

[0011] It should be noted that within this application process fluid pressure will be referred to as pressure, process fluid temperature will be referred to as temperature, the alternating differential pressure generated by the vortices shed from the shedder bar will be referred to as differential pressure, and polycrystalline silicon will be referred to as polysilicon.

Embodiment of the invention

[0012] A sensor housing is positioned in the shedder bar having for example two highly corrosion resistant process diaphragms on its outer edges for protecting the sensor from direct contact with the flow fluid yet able to transmit to the sensor the alternating pressure produced from the vortices as well as the process fluid's pressure and temperature. The interior of the sensor housing has sealed cavities containing a non-corrosive inert fluid which is used to transmit the pressure fluctuations, process fluid pressure, and temperature of the process flow from the process diaphragms to the sensor.

[0013] In a first sensor embodiment, the sensor contains two sensing diaphragms each with piezoresistors arranged in a Wheatstone bridge configuration. One sensing diaphragm is coupled to one of the process isolation diaphragms by an internal fluid filled cavity. The other side of this sensing diaphragm is positioned over a cavity which is either evacuated and sealed or, in the second sensor embodiment, vented to the atmosphere. This sensing diaphragm is used to measure either the absolute or gauge pressure of the process fluid. The second sensing diaphragm is connected on one side through a fluid filled cavity to one process diaphragm and on the other side through a second fluid filled

cavity to the other process diaphragm. The two fluid filled cavities are essentially isolated from each other. This sensing diaphragm is used to measure the amplitude and frequency of the differential pressure fluctuations caused by the shedding vortices. Either sensing diaphragm can measure the process fluid temperature as well.

[0014] In a first example of a vortex sensor not according to the present invention, the sensor element contains a single sensing diaphragm containing piezoresistors arranged in a Wheatstone bridge configuration. This sensing diaphragm is connected to both process diaphragms in the same manner as described above and is used to measure the amplitude and frequency of the differential pressure fluctuations caused by the vortices and is also used to measure the temperature.

[0015] In third and fourth sensor embodiments, the sensor contains two sensing diaphragms, used to measure the process fluid pressure and differential pressure fluctuations, that are structured in the same manner as in the aforementioned first and second sensor embodiments and contains an additional sensing element that is not mounted onto a diaphragm. The additional sensing element is the sole means for measuring the process fluid temperature eliminating this measurement from the two sensing diaphragms. The temperature sensing element contains two piezoresistors arranged in a series configuration and are positioned on the front side of the semiconductor chip which is connected to one process diaphragm through a fluid filled cavity.

[0016] In a further example of a vortex sensor not according to the present invention, the sensor contains one sensing diaphragm, used to measure the differential pressure fluctuations, that is structured in the same manner as in the aforementioned third sensor embodiment and contains an additional sensing element that is not mounted onto a diaphragm. This additional sensing element is the sole means for measuring the process fluid temperature eliminating this measurement from the sensing diaphragm. The temperature sensing element is structured in the same manner as in the aforementioned first sensor embodiment.

[0017] In all embodiments and examples, the sensor is fabricated of a polysilicon or silicon semiconductor chip. The chip is bonded to a laminated, substrate having circuit traces. Fine wires are connected between the piezoresistors and the circuit traces. In turn, the connection is made from the traces to a multipin hermetically sealed electrical feed through which can either be of glass to metal or ceramic to metal construction. A cable assembly carries the electrical signal from the feed through to the signal processor.

[0018] The functionality of the sensor is an improvement over the prior art in that it is capable of making a pressure measurement, a differential pressure measurement, and a temperature measurement at a common source point in the same process flow. In addition to these measurements, the computational element derives further measurement quantities indicative of the fluid such as, density, mass flow rate, absolute and kinematic viscosity, and Reynold's number. The ability to compute the Reynold's number is used to improve the flow velocity measurement accuracy.

[0019] General objects, features and advantages of the invention will be apparent from the following description of the preferred embodiments of the invention, as illustrated in the accompanying drawings in which like reference characters refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead being placed on illustrating the principles of the invention. In the drawings:

FIG. 1 is a view of a vortex flow meter having a flow sensor contained in a wafer meter body according to an embodiment of the invention;

FIG. 2 is a view of a vortex flow meter having a flow sensor contained in a flanged meter body according to an embodiment of the invention;

FIG. 3 is a view of the replaceable shedder bar assembly shown in FIG. 1;

FIG. 4 is a bottom view of the replaceable shedder bar assembly shown in FIG. 3 ;

FIG. 5 is a view of the meter body in which the replaceable shedder bar/sensor assembly resides;

FIG. 6 is a view of the bonnet assembly which secures the replaceable shedder bar/sensor assembly in the meter body ;

FIG. 7 is a view of a vortex flow meter having a flow sensor contained in a flanged meter body according to an embodiment of the invention;

FIG. 8 is a view of a vortex flow meter having a flow sensor contained in a wafer meter body according to the second embodiment of the invention;

FIG. 9 is view of the shedder bar/ sensor assembly;

FIG. 10 is an enlarged cross-sectional view of the first embodiment of the sensor taken along section A-A in FIG. 4 ;

FIG. 11 is an enlarged cross-sectional view of the first embodiment of the sensor taken along section B-B in FIG. 4;

FIG. 12 is an enlarged cross-sectional view of the second embodiment of the sensor taken along section A-A in FIG. 4 ;

FIG. 13 is a schematic diagram of the coupling of the sensing resistors in a Wheatstone bridge configuration useful will the present invention ;

FIG. 14 is a block diagram showing the processing element and its inputs and outputs as used in this invention ;

FIG., 15 is a cross sectional view of a vortex sensor not according to the present invention taken along section A-A in FIG. 4;

FIG. 16 is a cross sectional view of the third embodiment of the sensor taken along section B-B in FIG. 4 ;

FIG. 17 is a cross sectional view of a vortex sensor not according to the present invention taken along section B-B in FIG. 4;

FIG. 18 is a cross sectional view of the fourth embodiment of the sensor taken along section B-B in FIG. 4 ;

FIG. 19 is a schematic diagram of the coupling of the sensing resistors in a series configuration according to the third and fourth embodiments of the sensor.

[0020] A piezoresistive sensor for use in a vortex flowmeter having multimeasurement capabilities at a common source point within a single process penetration located within the stream of the fluid flow will be described below.

[0021] A flowmeter in accordance with the present invention is shown in FIGS. 1 and 2. The flowmeter comprises a meter body either in a wafer meter body 10a (see FIG.1) or a flanged meter body 10b (see FIG. 2) configuration to be coupled into a flow pipe (not shown) carrying fluid, the physical characteristics of which is to be determined. Mounted centrally in the meter body, in the path of the flowing fluid, is an elongate, upstanding body, generally indicated at 16a, serving as a composite vortex-generating and sensing unit. Shedder bar 16a is positioned on a diameter perpendicular to the flow stream and is used to develop strong, stable vortices of the process fluid. Furthermore, located in an interior chamber of circular cross-section and extending completely through sensor bar 16a is sensor 14.

[0022] Sensor 14 is generally circular in shape and is fitted with flexible metal corrosive resistant process diaphragms 38, 40 (see FIG. 10) used to isolate transducer 50a (see FIG. 10) from direct contact with the process fluid yet able to transmit the differential pressure fluctuations generated by the shedder bar and the process fluid pressure and temperature.

[0023] Referring to FIGS. 3, 4 and 5 shedder bar/sensor assembly 16a forms part of an elongate, integral meter member 24. The bottom end of integral meter member 24 contains tail piece 22 used to provide mechanical support for shedder bar assembly 16a thereby suppressing vibrations of the shedder bar caused by the process flow. Integral meter member 24 is situated into meter body 10 by passing vertically down through opening 26 at the top wall of the meter body through to the bottom wall sliding into pocket 27.

[0024] Referring to FIG. 3, the top of shedder bar 16a is connected to a circular metal base 28a having a top surface onto which is mounted fitting housing 30 used to protect electrical feed through fitting 42. Fitting 42 is used to transmit electronic signals produced from sensor 14 to cable assembly 48. This cable leads to processing element 82 (see FIG. 14) found in instrument housing 76 (see FIG. 1), which functions in known manner to produce conventional measurement signals 84 adapted for use in industrial process control. Fitting 42 is a hermetic multipin feed through plug, but the invention is not limited to this type of a fitting and any other type of suitable fitting may be used.

[0025] Referring again to FIG. 3, the bottom surface of circular metal base 28a contains circular teeth 12 used to seal integral member 24 to the meter body. A flat annular gasket 13 is placed between circular teeth 12 and meter body surface 19.

[0026] FIG. 6 depicts bonnet 25 which secures integral meter member 24 to the meter body and also to instrument housing 76 (see FIG. 1). Gasket 13 is clamped between bonnet 25 and meter body thereby containing the process fluid. The top outer edge 35 of bonnet 25 has a threaded surface for fastening bonnet 25 to instrument housing 76.. Bonnet 25 contains passage 33 which provides a passage way for cable assembly 48 to reach instrument housing 76 from integral meter member 24. Bolts 31a and 31b secure bonnet 25 to the meter body through clearance holes 34a and 34b in bonnet 25 to tapped holes 32a and 32b of the meter body (see FIG. 5). With such an arrangement, shedder

bar/sensor assembly 16a is readily removable from its operating position in the pipe section, as for calibration purposes, cleaning, replacement, or the like.

[0027] In the embodiment depicted in FIGS. 7 and 8, integral meter member 21 consists of shedder bar/sensor assembly 16b having its top surface mounted onto circular metal base 28b. Integral meter member 21 is welded into the meter body. The meter body is either in a wafer meter body 10a (FIG. 8) or in a flanged meter body 10b (FIG. 7) configuration to be coupled into a flow pipe (not shown). Bolted to the top surface of meter body 10b is bonnet 25 and fitting housing 30a which are structurally and operationally similar in all respects to the embodiment of Fig. 1 and 2.

[0028] In another embodiment, the shedder bar assembly is welded into meter body 10c as shown in FIG. 9. Meter body 10c is a round stainless steel pipe whose wall 20 has an inner surface of smoothness at least equal to a No. 4 mill finish. Meter body 10c is adapted to be coupled by means of sanitary end flanges 17 and 18 into a sanitary pipe system (not shown).

[0029] Mounted to the top surface of shedder bar 16c is circular metal base 28c, forming with shedder bar 16c, an elongate upstanding integral meter member 23. Meter member 23 is welded into meter body 10c such that all weld joints contain smooth flow contact surfaces. Attached to the top surface of base 28c is fitting housing 30b used to protect electrical feed through fitting 42. Fitting 42 is used to transmit electronic signals produced from sensor 14 to cable assembly 48. This cable leads to processing element 82 (see FIG. 14) which functions in known manner to produce conventional measurement signals 84 adapted for use in industrial process control.

[0030] Furthermore, meter body 10c, integral meter body 23, and sanitary end flanges 17 and 18 have smooth joint contact surfaces for low fluid and solids collectability, desirable for sanitary applications.

[0031] FIGS. 10 and 11 provide more detailed views of sensor 14. Between process diaphragms 38 and 40 is cavity 64 within which is positioned sensing transducer 50a which is used to detect the pressure fluctuations of the vortices as well as the pressure and temperature of the fluid. Sensing transducer 50a is a rectangular semiconductor chip fabricated of a polysilicon or silicon material. However, other geometric shapes can be used in accord with the invention, provided that at least one side of the chip is substantially flat. Sensing transducer 50a contains two sensing diaphragms 52 and 54 used to produce electric output signals responsive to differential pressure fluctuations, pressure, and temperature. Sensing diaphragms 52,54 are mounted onto laminated substrate 56. Laminated substrate 56 carries a layer of conductive traces 58 for transmitting output signals from the sensing diaphragms. Sensing transducer 50a is connected by multiple electrical wires 60 which are mounted from the outer edges of the sensing transducer to the layer of conductive traces 58. Details as to the further construction of the laminated substrate and the electrical connections from the sensing transducer to the laminated substrate are found in EP-A-0553725.

[0032] Referring to FIGS. 10 and 11, sensor 14 contains a fill port 74 for importing a non-corrosive inert fill fluid. The fill fluid enters through fill port 74 fills cavity 64 passes through a narrow slit 68 and fills cavity 35. It then fills bore 67 and cavity 70. Slit 68 establishes high mechanical or hydraulic impedance between cavity 64 and cavity 70. The fill path accordingly does not reduce the differential pressure fluctuations experienced by sensing diaphragm 52 relative to the differential pressure at process diaphragms 38,40, except at frequencies lower than those encountered during normal vortex-sensing operation. The fill fluid on both sides of sensing transducer 50a serves to transmit to sensing diaphragms 52,54 the pressure fluctuations, process fluid pressure and temperature applied to the outer surfaces of process diaphragms 38,40 by the passage of the process fluid and vortices shed by the shedder body 16. The fill fluid provides a desirably benign environment for the sensing transducer by protecting it from hostile fluids.

[0033] Slit 68 is large enough to allow fill fluid to seep therethrough yet small enough to form an apparent pressure barrier between cavity 64 and cavity 70. The slit is dimensioned to present a relatively high hydraulic impedance at the vortex frequencies being measured. Further, unequal pressure build-up within the hydraulic fluid on either side of the sensing transducer, as a result of temperature variations, is equalized by the passage of fluid from one compartment to another through slit 68.

[0034] Referring to FIG. 10, sensing diaphragm 52 senses the alternating differential pressure of the fluid flow and produces a corresponding electrical signal. Sensing diaphragm 54 senses the process fluid pressure and produces a corresponding electric signal. Either diaphragm 52 or 54 can be used to sense the process fluid temperature. Sensing diaphragms 52, 54 are formed of the same substantially flat face of a diaphragm chip, preferably fabricated of a polysilicon or silicon material. Piezoresistive strain gauges are disposed on each sensing diaphragm in a Wheatstone bridge configuration (see FIG. 13). Additionally, a dielectric layer can be interposed between the silicon or polysilicon diaphragm and the piezoresistors. This electrically isolates the resistors minimizing both unwanted leakage currents and resistance degradation at high process fluid temperature.

[0035] Referring to FIG. 13, the Wheatstone bridge consisting of four piezoresistor elements is positioned on the front face of sensing diaphragms 52, 54. The four piezoresistors 90, 92, 94, 96 are positioned on each sensing diaphragm such that when they are subject to movement of the sensing diaphragms due to pressure, piezoresistors 90, and 96 both experience either a compressive or a tensile strain while piezoresistors 92 and 94 simultaneously experience the opposite strain. Thus, if piezoresistors 92 and 94 are increasing in resistance, then piezoresistors 90 and 96 are decreasing in resistance. This in turn creates an imbalance across the bridge such that when current 102 passes

through the bridge from terminal 98a to 98b, a voltage V2 occurs across terminals 100a, 100b which is related to the movement of the diaphragm relative to the pressure being sensed as discussed below.

[0036] The temperature measurement is also made from piezoresistor elements. The value of the resistance of piezoresistors 90, 92, 94, 96 is a function of temperature. When constant drive current 102 is supplied to the Wheatstone bridge circuit, the voltage across drive terminals 98a, 98b is related to the equivalent resistance of the series-parallel combination of the four resistors between the drive terminals as discussed below. The equivalent resistance is primarily a function of temperature and, hence, used to compute the temperature.

[0037] Referring again to FIGS. 10 and 11, sensing diaphragm 52 has a reverse side with cavity 35 which is fluid filled. The fill fluid serves to transmit to the sensing diaphragm the pressure fluctuations applied to the process diaphragms by the passage of the vortices shed by the shedder bar 16. Sensing diaphragm 52 deflects due to the differential pressure transmitted through the fill fluid from process diaphragms 38, 40 produced by the alternating vortices. Such deflection causes a change in resistance which is detected by the internal Wheatstone bridge circuit producing a corresponding electric output signal. The output signal is transmitted to a processing element 82 (see FIG. 14) which determines the amplitude and frequency of the signal which is used to compute the fluid velocity and density.

[0038] Sensing diaphragm 54 is used to measure the absolute or gauge pressure of the process fluid. Sensing diaphragm 54 has a reverse side with sealed cavity 36 which is vacuum-filled when used to measure absolute pressure. In the second sensor embodiment, for a gauge pressure measurement, cavity 36 is vented to the atmosphere through atmosphere vent 66 (see FIG. 9). In sensing diaphragm 54, the deflection of the diaphragm due to pressure creates a change in resistance which is detected by the internal Wheatstone bridge circuit producing a corresponding electric output signal. In addition, sensing diaphragm 54 also deflects due to the pressure fluctuations generated by the vortices affecting process diaphragm 40. This deflection also creates a change in resistance which is detected by the internal Wheatstone bridge circuit. The resultant voltage output of the bridge is therefore a composite of the fluid pressure with a smaller a.c. component superimposed on it. The fluid pressure can be anywhere from approximately 1.4×10^5 Pa to 1.4×10^7 Pa (20 psi to 2000 psi) while the alternating differential pressure caused by the vortices can vary from approximately 70 Pa to 1×10^5 Pa (.01 psi to 15 psi). The processor element computes the average fluid pressure from this composite signal.

[0039] Additionally, either sensing diaphragms 52 or 54 can be used to measure the temperature of the fluid. The temperature of the fluid is sensed by the piezoresistor element in sensing diaphragms 52,54 which produces a corresponding output signal. The temperature measurement is also used to compensate, in processing element 82, for repeatable errors in the measurement of pressure and differential pressure caused by widely varying temperatures.

[0040] FIG. 15 depicts a vortex sensor not according to the present invention. In said vortex sensor, sensing transducer 50c consists of sensing diaphragm 52 used to produce electric output signals responsive to differential pressure fluctuations and temperature. Sensing diaphragm 52 used within sensing transducer 50c, in this embodiment, is similar in all other structural and operational details to the first sensor embodiment.

[0041] FIG. 16 depicts the third sensor embodiment of the invention. In the third sensor embodiment, sensing transducer 50d consists of two sensing diaphragms, 52 and 54, and sensing element 106. Sensing diaphragm 52 is used to measure the alternating differential pressure of the fluid flow and sensing diaphragm 54 measures the absolute pressure of the process fluid as detailed above in the first sensor embodiment and similar to FIG. 10. Sensing element 106 is used solely to measure the temperature of the process fluid. Neither sensing diaphragm 52 nor 54 is used to measure the process fluid temperature. The fourth sensor embodiment, as shown in FIG. 18, is similar to the third sensor embodiment, except that sensing diaphragm 54 is vented to the atmosphere measuring gauge pressure in a similar manner as in the second sensor embodiment and shown in FIG. 12.

[0042] The third and fourth sensor embodiments are particularly suited to polysilicon sensors, however, they can also be used with silicon sensors. Impurity doped polysilicon resistors have a very low temperature coefficient compared to silicon. To achieve an accurate temperature measurement, it is therefore highly desirable to physically isolate the temperature sensor from the mechanical strains experienced by the pressure sensing diaphragms. Referring to FIG. 19, sensing element 106 consists of two piezoresistor elements 108 and 110 arranged in a series configuration and used as a voltage divider. Piezoresistor elements 108, 110 are doped such that they have different temperature coefficients, preferably one with a negative and the other with a positive resistance temperature coefficient. The ratio of the voltages V1/V2 is a function of temperature.

[0043] FIG. 17 depicts a vortex sensor not according to the present invention where sensing transducer 50f comprises sensing diaphragm 52, used to measure the differential pressure fluctuations solely, and sensing element 106 which is used to measure temperature. This vortex sensor is also particularly suited to polysilicon sensors for the aforementioned reasons and could also be used with silicon.

[0044] A sensor designed in this fashion has the advantage of providing a more accurate temperature measurement since sensing element 106 is totally insensitive to mechanical strains thereby being unaffected by the differential pressure fluctuations or process fluid pressure. In the case where the sensing transducer is fabricated from a polysilicon semiconductor chip, it is imperative that the temperature measurement be made in this fashion in order to obtain an

accurate measurement. Polysilicon resistors have a low resistance temperature coefficient making it difficult to isolate the temperature effect when in combination with the effect of the differential or process fluid pressure.

[0045] The active or moving parts of sensor 14, namely, sensing diaphragms 52, 54, process diaphragms 38, 40, and the fill fluid have very low mass. Also, sensing diaphragms 52, 54 are extremely stiff. A sensor constructed in this manner has two advantages. It is inherently insensitive to mechanical vibrations such as lateral pipe vibrations. Secondly, it has a resonant frequency which is substantially higher than vibration frequencies which are typically experienced in piping, and is also substantially higher than the maximum shedding frequency. Therefore measurement errors caused by exciting the sensor at resonance do not occur, nor does the sensor fatigue due to excessive motion at resonance.

[0046] Referring to FIGS. 1, 2, 7, 8, and 14, instrument housing 76 contains processing element 82 used to produce measurement signals 84 derived from signals transmitted from sensor 14 transmitted through cable 48. Preferably, the processing element is a microprocessor. However, the invention is not limited to this use, other types of processing elements may be used.

[0047] Referring to FIG. 14, processing element 82 receives input signals 58 which are transmitted from sensor 14. Input signals 58 indicate the frequency and amplitude of the differential pressure fluctuations, temperature and pressure of the fluid's flow. From input signals 58, processing element 82 computes additional physical characteristics of the fluid's flow. These physical characteristics include, but are not limited to, the fluid's velocity, density, viscosity, Reynold's number, and mass flow rate. Details as to how these computations are derived are described below. These additional measurement quantities are transmitted from processing element 82 through measurement signals 84 for use in an industrial process control system.

[0048] The operation of the vortex flow meter and sensor will now be described in detail. When the process fluid flows through the flow pipe, vortices are generated by the shedder bar which in turn generate the alternating vortex pressure fluctuations. These pressure fluctuations as well as the fluid pressure and temperature are transmitted to sensor 14. Process diaphragms 38, 40 serve to isolate the process fluid from the sensing transducer while transmitting the alternating vortex pressure fluctuations, pressure, and temperature of the fluid through the fill fluid to sensing diaphragms 52, 54.

[0049] The alternating vortices cause pressure fluctuations which are transmitted through the fill fluid on both sides of sensing diaphragm 52 causing it to deflect in response to the resultant alternating pressure. As a result the piezoresistors in sensing diaphragm 52 experience an alternating strain resulting in a sinusoidal variation in resistance producing an a.c. voltage signal. This signal is transmitted from sensing diaphragm 52 through to conductive traces 58 through fitting 42 to cable 48 and onto processing element 82. This a.c. voltage signal will be sinusoidal in nature from which its frequency and amplitude is computed in known fashion by processing element 82. Since sensing diaphragm 52 only senses differential pressure and is relatively immune to fluid pressure, sensor 14 has excellent inherent common mode noise rejection and immunity to pump pulsations. Therefore, there is little possibility that processing element 82 will interpret pump pulsations as being vortex shedding pressure fluctuations and compute an erroneous flow velocity.

[0050] The alternating pressure caused by the vortex shedding is transmitted from process diaphragms 38, 40 through the fill fluid to the two sides of sensing diaphragm 52. The process fluid pressure is transferred from process diaphragm 40 through the fill fluid to the top side of sensing diaphragm 54. Typically the amplitude of the alternating differential pressure is between +/- 137.9 Pa (.02 psi) to +/- 1.034×10^5 Pa (15 psi) depending on the flow velocity and the process fluid density. The process fluid pressure might be anywhere from 1.379×10^5 Pa (20 psi) to 1.379×10^7 Pa (2000 psi). Therefore, the pressure experienced by sensing diaphragm 54 is largely the process fluid pressure which is basically steady, plus a smaller sinusoidal component caused by the shedding vortices. The processing electronics extracts the average pressure.

[0051] Independently, a temperature measurement is made as well from sensing diaphragms 52 or 54. There is a constant drive current applied to the Wheatstone bridge circuit at terminal 102. The temperature measurement is made by measuring the voltage across drive terminals 98a, 98b at a constant drive current. The voltage from drive terminals 98a, 98b produces a resultant d.c. voltage indicative of the temperature of the fluid. The temperature measurement can be made from either sensing diaphragms 52 or 54. However, this invention is not limited to this embodiment. In alternative embodiments, the temperature measurement can be made from either one of the sensing diaphragms or from a third location on the semiconductor chip having piezoresistors but no diaphragm.

[0052] In the third and fourth sensor embodiments, the process fluid temperature measurement is made from two piezoresistors, 108, 110 arranged in a series configuration situated on the front face of the semiconductor chip subjected to the process fluid temperature from process diaphragm 40. A current is applied to piezoresistors 108, 110 at terminal 116. The temperature measurement is made by measuring the voltage across terminals 112a and 112b in proportion to the voltage across terminals 114a and 114b as described in detail below.

[0053] Hence, the outputs from sensor 14 are electronic signals indicative of the frequency and differential pressure amplitude of the shedding vortices, the fluid's gauge or absolute pressure, P, and the temperature, T. These and other measurements are computed by processing element 82 as follows:

1. The flow velocity, Vf, is computed from the following relation:

$$Vf = C_1 * fs,$$

where

C_1 is a known calibration constant which is a function of the flowmeter internal diameter and the shedder bar geometry and

fs is the vortex shedding frequency.

2. The temperature measurement, T, made in the first and second sensor embodiments is primarily a function of the voltage V1 across drive terminals 98a, 98b (see FIG. 7) of the Wheatstone bridge which in turn is proportional to the equivalent resistance at these terminals. The equivalent resistance is also affected somewhat by the pressure if sensing diaphragm 54 is used to measure temperature, or by the differential pressure if sensing diaphragm 52 is used to measure temperature. Thus at a constant drive current, the temperature is computed from an equation of the general form:

$$T = \sum_{q=0}^{q} \sum_{r=0}^{r} a_{qr} V_1^{q} V_2^{r}$$

where a_{qr} are calibration constants and V_1, V_2 are the measured voltages.

3. The alternative temperature measurement, T, made in the third and fourth sensor embodiments is in proportion to voltages 112 and 114 across piezoresistors 108, 110. Piezoresistors 108 and 110 are such that they have different temperature coefficients. This measurement, unlike the temperature measurement above, is not affected by the process fluid pressure or differential pressure fluctuations. The general form of the temperature measurement is computed from the following relation:

$$T = 1 + A_1 (V_1 / V_2) + A_2 (V_1 / V_2)^2 + \ldots + A_n (V_1 / V_2)^n$$

where

V_1 and V_2 are the measured voltages and

$A_1, A_2, \ldots, A_n$ are calibration constants.

4. The pressure measurement, P, is primarily a function of the voltage V2 across terminales 100a, 100b of the bridge circuit on sensing diaphragm 54 (see FIG. 7). The measurement is slightly affected by the temperature of the sensing diaphragm. Thus, at a constant drive current, the pressure is computed from an equation of the following general form:

$$P = \sum_{n=0}^{n} \sum_{m=0}^{m} b_{nm} V_1^{n} V_2^{m}$$

where

b_{nm} are calibration constants and

V_1, V_2 are the measured voltages.

5. Similarly the measurement of the amplitude of the alternating differential pressure is primarily a function of the voltage V2 across terminals 100a and 100b of the bridge circuit on sensing diaphragm 52 (see FIG. 7). This measurement is also affected by the temperature of the sensing diaphragm. Thus, at a constant drive current, the differential pressure is computed from an equation of the same general form as the pressure discussed in 4 above.

6. The process fluid density, d, can be computed by the following relations for the sensor described in the sensor embodiments of the invention as follows:

a) For an ideal gas, $d = P / (R * T)$, where R is the known gas constant and P and T are the measured pressure and temperature signals computed as shown in (2), (3), and (4).

b) For a liquid, $d = d_0 * (1 + B_1 * (P-P_a))/ (1 + B_2 * (T-T_0))$ where T_0 is a reference temperature, P_a is a reference pressure, d_0 is the density at reference temperature T_0 and reference pressure P_a, B_1 and B_2 are known compressibility and expansion factors, and P and T are the pressure and temperature computed as shown in (2), (3), and (4).

7. An alternative method for computing the process fluid density, d, for any embodiment is from the average alternating differential pressure created by the shedding vortices across the sensor and the flow velocity measurement. This relation is as follows:
d = differential pressure/ $(C_2 * Vf^2)$, where C_2 is a known constant and Vf is computed as shown in (1) above.

8. A computation of the expected sensor signal V2 across terminals 100a, 100b of the bridge circuit of the differential pressure sensing diaphragm 52 can be used as a diagnostic to determine whether the sensor and its associated electronics are functioning correctly. The expected signal V2 is proportional to the product of the fluid density times the flow velocity squared. For example, if the fluid density is computed as in 6a or 6b and the flow velocity is computed as in 1 above, then the expected signal is:

$$V2 = C_3 * d * Vf^2$$

where C_3 is a calibration constant.

9. The absolute viscosity v of the process fluid is a function of the process fluid temperature and is computed from the relationship between the temperature and absolute viscosity, which must be known for the particular process fluid.

10. The kinematic viscosity, kv, of the fluid is determined from the following relation:
kv = v/d, where v is the absolute viscosity computed as shown in (9) above and d is the density computed as shown from (6) or (7) above.

11. The Reynold's number, R, is determined from the following relation:
R = (Vf * D)/kv, where Vf is the velocity computed as shown in (1), D is the flowmeter internal diameter, and kv is the kinematic viscosity computed as shown in (10) above.
The accuracy of the flow velocity computation can be improved if the Reynold's number is known. This is due to the fact that the shedder bar geometry C_1 is not constant, rather varies in a known fashion with the Reynold's number.

12. The mass flow rate of both liquids and gases is determined from the following relation:
MFR = d * a * Vf, where d is the density computed as shown in (6) and (7) above, Vf is the flow velocity computed as shown in (1), and a is the area of the flowmeter bore.

[0054] The multimeasurement capabilities described above are attributable to the properties of the piezoresistor element. Piezoresistors can be applied to measure a.c. pressure fluctuations which are generated by vortex shedding as well as the process fluid's pressure and temperature which are often quite steady. This is an improvement over the prior art which employed piezoelectric crystals which had by their nature the limited capability of being able to measure only a.c. pressure fluctuations.

[0055] Additionally, this invention is a beneficial improvement since it has the capability to measure in a single flow penetration the fluid's differential pressure, temperature, and pressure from which other physical characteristics of the flow can be computed. Such other characteristics include, but are not limited to, the density of the fluid, the absolute viscosity, kinematic viscosity, the Reynold's number, and the mass flow rate. There is also the additional benefit of an increased accuracy in the measurements since they were measured from a common sampling point.

[0056] Furthermore, a sensor located in the shedder bar directly with the stream of the fluid flow produces a more accurate measurement of the amplitude of the shedding frequency. This measurement, in turn, produces a more accurate computation of the flow density. The construction of a replaceable shedder bar/sensor assembly is an added improvement since the sensor can be easily removed for calibration, replacement, cleaning and the like. The construction of the shedder bar/sensor assembly having smooth flow contact surfaces is beneficial for sanitary applications where low fluid and solids collectability is essential.

[0057] While the foregoing description of the preferred embodiments have considered resistive sensing other known sensing techniques can be used. For example, conventional resistance strain gauges, capacitance sensing, or optical sensing may be employed in lieu of the piezoresistor sensing techniques used in this invention.

[0058] Although the preferred embodiments of the invention have been described hereinabove in detail, it is desired to emphasize that this is for the purpose of illustrating the invention and thereby to enable those skilled in this art to adapt the invention to various different applications within the scope of the present invention which is defined by the claims.

Claims

1. A flow-metering apparatus (10) of the vortex-generating type comprising:

    a) a flow-pipe section adapted to be coupled into a fluid conduit flow;
    b) a vortex-generating body (16a) mounted in the interior of said flow-pipe section perpendicular to the stream of flowing fluid, said vortex-generating body (16a) having side edges producing corresponding alternating vortices;
    c) a mounting means for securing said vortex-generating body (16a) to the interior of said flow-pipe section;
    d) a sensor housing (16a) mounted within said vortex-generating body (16a) having sealed interior spaces (64,70), said sensor housing (16a) being adapted to be fluidly connected to said fluid flow;
    e) first and second process diaphragm means (40,38) forming part of said sensor housing (16a) to contact the flowing fluid and to transmit into said sealed interior spaces (64,70) alternating pressure fluctuations corresponding to the alternating vortices generated by said vortex-generating body (16a);
    f) sensor means (14) located inside of said sensor housing (16a) having opposite sides subjected respectively to said pressure fluctuations transmitted by said first and second process diaphragms (40,38), said sensor means (14) being arranged to detect said pressure fluctuations;
    g) liquid fill in said sealed spaces (64,70) surrounding said sensor means (14) for transmitting within said sealed interior spaces (64,70) said pressure fluctuations;
    h) electrical transmission means connected to said sensor means (14) to conduct signals corresponding to said pressure fluctuations; and
    i) computation means connected to said electrical transmission means arranged to process output signals transmitted from said electrical transmission means and arranged to produce electronic signals indicative of physical measurement quantities of the flow;
    j) the first and second process diaphragms (40,38) also transmitting into said sealed interior spaces (64,70) process fluid pressure and temperature of the fluid; and **characterized in that** :
    k) the sensor means (14) is subject to, and arranged to detect, said process fluid pressure and said temperature of the process fluid, said sensor means (14) comprising a first and a second sensing diaphragm (52,54) such that said first sensing diaphragm (52) is sensitive to said pressure fluctuations and is situated between opposite sides of said first and second process diaphragm means (40,38) such that it is coupled on one side via the liquid fill to the first process diaphragm and on its other side via the liquid fill to the second process diaphragm, and said second sensing diaphragm (38) is coupled to only the first process diaphragm with a single side exposed to the liquid fill;
    l) the electrical transmission means conducting signals corresponding to said process fluid pressure and temperature.

2. Apparatus (10) as in claim 1, wherein either said first sensing diaphragm (52) or said second sensing diaphragm (54) is configured to be sensitive to changes in temperature.

3. Apparatus (10) as in claim 1, wherein said sensor means (14) further comprises a temperature sensing element (106) which varies with changes in said process fluid temperature having a single side subject to said temperature changes from said first process diaphragm (40) which are transmitted via the liquid fill.

4. Apparatus (10) as in claim 1, in which said sensor means (14) is fabricated from the group consisting of a polysilicon semiconductor chip or silicon semiconductor chip.

5. Apparatus (10) as in claim 1, in which said sensor means (14) contains fiezoresistive elements (90,92,94,96) for sensing changes due to said pressure fluctuations, process fluid pressure, and temperature.

6. Apparatus (10) as in any preceding claim, where said mounting means'comprises a replaceable mounting element (28b) for removing said vortex-generating body (16a) from the interior of said flow-pipe section.

7. Apparatus (10) as in any preceding claim, where said mounting means comprises an element (28c) for permanently securing said vortex-generating body (16a) to the interior of said flow-pipe section.

8. Apparatus (10) as in claim 7, wherein said vortexgenerating body (16a), said flow-pipe section, and said securing element presenting surfaces accessible to said fluid flow that have low fluid collectability, thereby preventing entrapment of said fluid and entrained solids.

9. A method of determining characteristics of a process flow comprising:

a) mounting a vortex-generating body (16a) in the interior of a flow-pipe section perpendicular to the stream of flowing fluid, said vortex-generating body (16a) having side edges producing corresponding alternating vortices by securing said vortex-generating body (16a) to the interior of said flow-pipe section by a mounting means;
b) mounting a sensor housing (16a) within. said vortexgenerating body (16a) having liquid filled sealed interior spaces, said sensor housing (16a) fluidly connected to said fluid flow;
c) producing by said vortex-generating body (16a) a series of alternating pressure vortices in a flow stream by mounting the vortex-generating body (16a) in said flow-pipe section;
d) transmitting said alternating pressure vortices (16a) caused by said vortex-generating body (16a) to a sensor means (14) enclosed in the sensor housing (16a) and, the sensor housing (16a) formed in part with a first and second process diaphragms (40,38) in contact with said process fluid, transmitting said alternating pressure vortices to said sensor means (14) through said liquid fill which surrounds said sensor means (14);
e) measuring said alternating pressure vortices caused by said vortex-generating body (16a) at said sensor means (14) by a first sensing diaphragm (52) having opposite sides subjected to said alternating pressure vortices from said first and second process diaphragms (40,38) such that it is coupled on one side via the liquid fill to the first process diaphragm and on its other side via the liquid fill to the second process diaphragm ;
f) computing the amplitude of differential pressure and frequency of said alternating pressure vortices as measured from said sensor means (14); and **characterized by**:
g) transmitting via the liquid fill the process fluid pressure to said sensor means (14);
h) measuring said process fluid pressure with said sensor means (14) by a second sensing diaphragm (54) which is coupled to only the first process diaphragm with a single side exposed to the liquid fill ; and
i) measuring said process fluid temperature at said sensor means (14) which varies with changes in said temperature.

10. The method claimed in claim 9 wherein the step of measuring said process fluid temperature is made at said sensor means (14) by said first sensing diaphragm (52) which varies with changes in said temperature.

11. The method claimed in claim 9 wherein the step of measuring said process fluid temperature is made at said sensor means (14) by said second sensing diaphragm (54) which varies with changes in said temperature.

12. The method claimed in claim 9 wherein the step of measuring said process fluid temperature is done at said sensor means (14) by a temperature sensing element (106) which varies with changes in said process fluid temperature having a single side subject to said temperature changes from said first process diaphragm (40) and spaced from said first and second sensing diaphragms (52,54).

13. The method claimed in any one of claims 9 to 12 further comprising the steps of:

a) computing the flow velocity, Vf, as a function of said frequency of altemating pressure vortices as measured from said sensor means (14);
b) determining the process fluid density, as a function of said process fluid pressure and temperature as determined from said sensing means (14); and
C) computing the mass flow rate MFR from the equation

$$MFR = d \times a \times Vf$$

wherein d is said process fluid density and a is the cross-sectional area of the flow pipe.

Patentansprüche

1. , Durchflußmeßvorrichtung (10) des wirbelerzeugenden Typs aufweisend:

a) einen Strömungsrohrabschnitt, der derart angepaßt ist, daß er mit dem Strom einer Flüssigkeitsleitung verbunden werden kann;
b) einen wirbelerzeugenden Körper (16a), der im Innern des Strömungsrohrabschnittes und senkrecht zu dem Strom des Fluides angeordnet ist, wobei der wirbelerzeugende Körper (16a) Seitenkanten aufweist, die entsprechende abwechselnde Wirbel erzeugen;
c) ein Befestigungsmittel zur Sicherung des wirbelerzeugenden Körpers (16a) im Innern des Strömungsrohrabschnittes;
d) ein Sensorgehäuse (16a), das innerhalb des wirbelerzeugenden Körpers (16a) angeordnet ist, mit versiegelten Innenräumen (64,70), wobei das Sensorgehäuse (16a) derart angepaßt ist, daß dieses strömend mit dem Fluidstrom verbunden ist;
e) erste und zweite Prozeßmembraneinrichtungen (40,38), die einen Teil des Sensorgehäuses (16a) ausbilden, um das fließende Fluid zu kontaktieren und abwechselnde Druckschwankungen entsprechend den abwechselnden Wirbeln, die durch den wirbelerzeugenden Körper (16a) erzeugt werden, in die versiegelten Innenräume (64,70) zu übertragen,
f) eine Meßeinrichtung (14), die innerhalb des Sensorgehäuses (16a) angeordnet ist, mit gegenüberliegenden Seiten, die jeweils den Druckschwankungen, die durch die erste und zweite Prozeßmembran (40,38) übertragen werden, ausgesetzt sind, wobei die Meßeinrichtung (14), derart angeordnet ist, daß die Druckschwankungen erfaßt werden;
g) Flüssigkeitsfüllung in den versiegelten Räumen (64,70), die die Meßeinrichtung (14) umgibt, zur Übertragung der Druckschwankungen innerhalb der versiegelten Innenräume (64,70);
h) elektrische Übertragungsmittel, die mit der Meßeinrichtung (14) verbunden sind, um Signale weiterzuleiten, die mit den Druckschwankungen korrespondieren; und
i) mit den elektrischen Übertragungsmitteln verbundene Berechnungsmittel, die derart angeordnet sind, daß ein Ausgangssignal, das von den elektrischen Übertragungsmitteln übertragen wird, und daß ein elektrisches Signal, das indikativ für physikalische Meßgrößen des Durchflusses ist, erzeugt wird;
j) wobei die erste und zweite Prozeßmembran (40,38) ebenso Prozeßfluiddruck und -temperatur des Fluides in die versiegelten Innenräume (64,70) übertragen; **dadurch gekennzeichnet, daß**:
k) die Meßeinrichtung (14) ausgebildet und angeordnet ist, um den Prozeßfluiddruck und die Temperatur des Prozeßfluides zu erfassen, wobei die Meßeinrichtung (14) eine erste und eine zweite Meßmembran (52,54) aufweist, so daß die erste Meßmembran (52) sensibel gegenüber Druckschwankungen ist und zwischen gegenüberliegenden Seiten von der ersten und zweiten Prozeßmembraneinrichtung (40,38) angeordnet ist, so daß sie auf einer Seite über die Flüssigkeitsfüllung mit der ersten Prozeßmembran und auf ihrer anderen Seite über die Flüssigkeitsfüllung mit der zweiten Prozeßmembran verbunden ist, und die zweite Meßmembran (38) nur mit der ersten Prozeßmembran verbunden ist, wobei eine einzelne Seite der Flüssigkeitsfüllung ausgesetzt ist;
1) die elektrischen Übertragungsmittel Signale leiten, die dem Prozeßfluiddruck und der Prozeßfluidtemperatur entsprechen.

2. Vorrichtung (10) nach Anspruch 1, bei der entweder die erste Meßmembran (52) oder die zweite Meßmembran (54) derart ausgebildet ist, daß diese sensibel auf Änderungen der Temperatur reagiert.

3. Vorrichtung (10) nach Anspruch 1, bei der die Meßeinrichtung (14) ferner ein Temperaturmesselement (106) auf-

weist, das in Abhängigkeit von Änderungen der Prozeßfluidtemperatur variiert und eine einzelne Seite aufweist, die den Temperaturänderungen von der ersten Prozeßmembran (40) ausgesetzt ist, die über die Flüssigkeitsfüllung übertragen werden.

4. Vorrichtung (10) nach Anspruch 1, bei der die Meßeinrichtung (14) aus Materialien einer Gruppe hergestellt ist, die aus einem Polysiliziumhalbleiterchip oder Siliziumhalbleiterchip besteht.

5. Vorrichtung (10) nach Anspruch 1, bei der die Messeinrichtung (14) Piezowiderstandselemente (90,92,94,96) zur Messung von Veränderungen aufgrund der Druckschwankungen des Prozeßfluiddruckes und der Temperatur beinhaltet.

6. Vorrichtung (10) nach einem der vorangehenden Ansprüche, bei der das Befestigungsmittel ein austauschbares Befestigungselement (28b) zum Entfernen des wirbelerzeugenden Körpers (16a) aus dem Innern des Strömungsrohrabschnittes aufweist.

7. Vorrichtung (10) nach einem der vorangehenden Ansprüche, bei der das Befestigungsmittel ein Element (28c) zur dauerhaften Sicherung des wirbelerzeugenden Körpers (16a) im Innern des Strömungsrohrabschnittes aufweist.

8. Vorrichtung (10) nach Anspruch 7, bei der der wirbelerzeugende Körper (16a), der Strömungsrohrabschnitt und das Sicherungselement Oberflächen zur Verfügung stellen, die für den Fluidstrom zugänglich sind und eine geringe Fluidverbindbarkeit haben, wodurch ein Einschließen des Fluides und mitgerissener Festkörper verhindert wird.

9. Ein Verfahren zur Ermittlung der Charakteristika eines Prozeßstromes aufweisend:

a) Anordnen eines wirbelerzeugenden Körpers (16a) im Innern eines Strömungsrohrabschnittes, rechtwinklig zu dem Strom des fließenden Fluides, wobei der wirbelerzeugende Körper (16a) Seitenkanten aufweist, die entsprechende abwechselnde Wirbel erzeugen, durch Sichern des wirbelerzeugenden Körpers (16a) im Innern des Strömungsrohrabschnittes durch ein Befestigungsmittel;
b) Anordnen eines Sensorgehäuses (16a) innerhalb des wirbelerzeugenden Körpers (16a), das flüssigkeitsbefüllte, versiegelte Innenräume aufweist, wobei das Sensorgehäuse (16a) strömend mit dem Fluidstrom verbunden ist;
c) Erzeugen einer Serie von abwechselnden Druckwirbeln in einem fließenden Strom durch den wirbelerzeugenden Körper (16a) durch Anordnen des wirbelerzeugenden Körpers (16a) in dem Strömungsrohrabschnitt;
d) Übertragen der abwechselnden Druckwirbel (16a), die durch den wirbelerzeugenden Körper (16a) erzeugt werden, zu einer Meßeinrichtung (14), die in dem Sensorgehäuse (16a) eingeschlossen ist, wobei das Sensorgehäuse (16a), das zum Teil mit einer ersten und einer zweiten Prozeßmembran (40,38) ausgebildet ist, die in Kontakt mit der Prozeßflüssigkeit stehen, die die abwechselnden Druckwirbel über die Flüssigkeitsfüllung, die die Meßeinrichtung (14) umgibt, zu der Meßeinrichtung (14) überträgt;
e) Messen der abwechselnden Druckwirbel, die durch den wirbelerzeugenden Körper (16a) erzeugt werden, bei der Meßeinrichtung (14) durch eine erste Meßmembran (52), die gegenüberliegende Seiten aufweist, die den abwechselnden Druckwirbeln der ersten und der zweiten Prozeßmembran (40,38) ausgesetzt sind, so daß sie auf der einen Seite über die Prozeßmembran und auf ihrer anderen Seite über die Flüssigkeitsfüllung mit der zweiten Prozeßmembran gekoppelt ist;
f) Berechnung der Amplitude der unterschiedlichen Drücke und Frequenzen der abwechselnden Druckwirbel, wie sie von der Meßeinrichtung (14) gemessen wurden, **gekennzeichnet durch**:
g) Übertragen des Prozeßfluiddruckes zu der Meßeinrichtung (14) über die Flüssigkeitsfüllung;
h) Messen des Prozeßfluiddruckes mit der Meßeinrichtung (14) **durch** eine zweite Meßmembran (54), die lediglich mit der ersten Prozeßmembran mit einer einzelnen Seite, die der Flüssigkeitsfüllung ausgesetzt ist, gekoppelt ist, und
i) Messen der Prozeßfluidtemperatur bei der Meßeinrichtung (14), die auf Änderungen der Temperatur reagiert.

10. Verfahren nach Anspruch 9, bei dem der Schritt des Messens der Prozeßfluidtemperatur bei der Meßeinrichtung (14) durch die erste Meßmembran (52) durchgeführt wird, die auf Änderungen der Temperatur reagiert.

11. Verfahren nach Anspruch 9, bei dem der Schritt des Messens der Prozeßfluidtemperatur bei der Meßeinrichtung (14) durch die zweite Meßmembran (54) durchgeführt wird, die auf Änderungen der Temperatur reagiert.

12. Verfahren nach Anspruch 9, bei dem der Schritt des Messens der Prozeßfluidtemperatur bei der Meßeinrichtung

(14) durch ein Temperaturmeßelement (106) durchgeführt wird, das auf Änderungen der Prozeßflüssigkeitstemperatur reagiert und eine einzelne Seite aufweist, die den Temperaturänderungen von der ersten Prozessmembran (40) ausgesetzt ist und die von der ersten und zweiten Meßmembran (52,54) beabstandet ist.

13. Verfahren nach einem der Ansprüche 9 - 12, ferner aufweisend die Schritte:

a) Berechnung der Strömungsgeschwindigkeit Vf, als eine Funktion der Frequenz der abwechselnden Druckwirbel, wie sie von der Meßeinrichtung (14) gemessen wurden;
b) Bestimmung der Prozeßfluiddichte als eine Punktion des Prozeßfluiddruckes und der Prozeßfluidtemperatur wie diese von der Meßeinrichtung (14) bestimmt wurden; und
c) Berechnung des Massendurchsatzes (MFR) aus der Gleichung

$$MFR = d \times a \times Vf,$$

wobei d die Prozeßfluiddichte und a der Querschnittsbereich des Strömungsrohres ist.

Revendications

1. Dispositif (10) de mesure d'écoulement du type à génération de vortex comportant :

a) une section de tube d'écoulement adaptée pour être raccordée à une conduite d'écoulement hydraulique ;
b) un corps (16A) de génération de vortex monté à l'intérieur de ladite section de tube d'écoulement perpendiculairement au cours du fluide s'écoulant, ledit corps (16A) de génération de vortex ayant des bords de côté produisant des remous en alternance correspondants ;
c) des moyens d'assemblage pour fixer ledit corps (16A) de génération de vortex à l'intérieur de ladite section de tube d'écoulement ;
d) un logement (16A) de capteur monté à l'intérieur dudit corps (16A) de génération de vortex, ayant des espaces (64,70) intérieurs scellés, ledit logement (16A) de capteur étant adapté pour être raccordé hydrauliquement audit écoulement hydraulique ;
e) des premiers et seconds moyens (40,38) formant diaphragme d'exploitation faisant partis dudit logement (16A) de capteur pour entrer en relation avec le fluide s'écoulant et pour transmettre à l'intérieur desdits espaces (64,70) intérieurs scellés des fluctuations de pression en alternance correspondant aux remous en alternance générés par ledit corps (16A) de génération de vortex ;
f) des moyens (14) de mesure logés à l'intérieur dudit logement (16A) de capteur, ayant des cotés opposés soumis respectivement auxdites fluctuations de pression transmises par lesdits premiers et seconds diaphragmes (40,38) d'exploitation, lesdits moyens (14) de mesure étant adaptés pour détecter lesdites fluctuations de pression ;
g) un liquide de remplissage dans lesdits espaces (64,70) scellés entourant lesdits moyens (14) de mesure, pour transmettre à l'intérieur desdits espaces (64,70) intérieurs scellés lesdites fluctuations de pression ;
h) des moyens de transmission électrique raccordés auxdits moyens (14) de mesure pour transporter lesdits signaux correspondants auxdites fluctuations de pression ;
i) des moyens de calcul raccordés auxdits moyens de transmission électrique, aptes à traiter des signaux de sortie transmis par lesdits moyens de transmission électrique, et adaptés pour produire des signaux électroniques représéntatifs des grandeurs mesurées physiquement de l'écoulement
j) le premier et le second diaphragmes (40,38) d'exploitation transmettant également à l'intérieur desdits espaces (64,70) intérieurs scellés, la pression du fluide d'exploitation est la température du fluide, et **caractérisé en ce que** :
k) les moyens (14) de mesure sont soumis à, et adaptés pour détecter ladite pression du fluide d'exploitation et ladite température du fluide d'exploitation, lesdits moyens (14) de mesure comportant un premier et un second diaphragmes (52,54) de mesure tel que ledit premier diaphragme (52) de mesure est sensible auxdites fluctuations de pression et est disposé entre les cotés opposés desdits premiers et seconds moyens (40, 38) formant diaphragme d'exploitation de telle façon qu'il soit raccordé sur un côté par l'intermédiaire du liquide de remplissage au premier diaphragme d'exploitation et sur son autre côté par l'intermédiaire du liquide de remplissage au second diaphragme d'exploitation, et ledit second diaphragme (38) de mesure est raccordé seulement au premier diaphragme d'exploitation avec un seul coté exposé au liquide de remplissage ;
l). les moyens de transmission électrique transportant les signaux correspondant à ladite pression du fluide

d'exploitation et à la température.

2. Dispositif (10) selon la revendication 1, dans lequel soit ledit premier diaphragme (52) de mesure ou soit ledit second diaphragme (54) de mesure est configuré pour être sensible au changement de température.

3. Dispositif (10) selon la revendication 1, dans lequel lesdits moyens (14) de mesure comportent en outre un élément (106) de mesure de température qui varie avec les changements de ladite température du fluide d'exploitation, ayant un seul coté soumis auxdits changements de température à partir dudit premier diaphragme (40) d'exploitation, qui sont transmis par l'intermédiaire du liquide de remplissage.

4. Dispositif (10) selon la revendication 1, dans lequel lesdits moyens (14) de mesure sont fabriqués à partir du groupe composé d'une puce semi-conductrice en polysilicium ou d'une puce semi-conductrice en silicium.

5. Dispositif (10) selon la revendication 1, dans lequel les moyens (14) de mesure comportent des éléments pie20 résistifs (90,92,94,96) pour mesurer les changements dus auxdites fluctuations de pression, à la pression du fluide d'exploitation, et à la température.

6. Dispositif (10) selon l'une quelconque des revendications précédentes, dans lequel lesdits moyens d'assemblage comportent un élément d'assemblage remplaçable (28B) pour enlever ledit corps (16A) de génération de vortex de l'intérieur de la section de tube d'écoulement.

7. Dispositif (10) selon l'une quelconque des revendications précédentes, dans lequel lesdits moyens d'assemblage comportent un élément (28C) pour fixer de façon permanente ledit corps (16A) de génération de vortex à l'intérieur de ladite section de tube d'écoulement.

8. Dispositif (10) selon la revendication 7, dans lequel le corps (16A) de génération de vortex, ladite section du tube d'écoulement, et ledit élément de fixation comporte des surfaces accessibles auxdits écoulements hydrauliques qui ont une faible recueillabilité de fluide, empêchant par là le piégeage dudit fluide et de solides transportés.

9. Procédé de détermination de caractéristiques d'un écoulement d'exploitation comportant les étapes de :

a) monter un corps (16A) de génération de vortex à l'intérieur d'une section de tube d'écoulement perpendiculairement au cours du fluide s'écoulant, ledit corps (16A) de génération de vortex ayant des bords de coté produisant des remous en alternance correspondants en fixant ledit corps (16A) de génération de vortex à l'intérieur de ladite section de tube d'écoulement à l'aide de moyens d'assemblage :
b) monter un logement (16A) de capteur à l'intérieur dudit corps (16A) de génération de vortex, ayant des espaces intérieurs scellés remplis de liquide, ledit logement (16A) de capteur étant raccordé hydrauliquement audit écoulement hydraulique
c) produire à l'aide dudit corps (16A) de génération de vortex une série de remous de pression en alternance dans un courant d'écoulement en montant le corps (16A) de génération de vortex dans ladite section de tube d'écoulement ;
d) transmettre lesdits remous (16A) de pression en alternance, provoqués par ledit corps (16A) de génération de vortex à des moyens (14) de mesure logés à l'intérieur du logement (16A) de capteur et, le logement (16A) de capteur, formé en partie avec un premier et un second diaphragmes (40,38) d'exploitation en contact avec ledit fluide d'exploitation, transmettant lesdits remous de pression en altemance auxdits moyens (14) de mesure par l'intermédiaire dudit liquide de remplissage qui entoure lesdits moyens (14) de mesure ;
e) mesurer lesdits remous de pression en alternance provoqués par ledit corps (16A) de génération de vortex, auxdits moyens (14) de mesure par un premier diaphragme (52) de mesure ayant des côtés opposés soumis auxdits remous de pression en alternance à partir desdits premier et second diaphragmes (40,38) d'exploitation de telle façon qu'il est raccordé sur un côté par l'intermediaire du liquide de remplissage au premier diaphragme d'exploitation et sur son autre côté, par l'intermédiaire du liquide de remplissage, au second diaphragme d'exploitation ;
f) calculer l'amplitude d'une pression différentielle et une fréquence desdits remous de pression en alternance tels que mesurés à partir desdits moyens (14) de mesure; et **caractérisé en ce qu'**il comporte les étapes de ;
g) transmettre par l'intermédiaire du liquide de remplissage la pression du fluide d'exploitation auxdits moyens (14) de mesure ;
h) mesurer ladite pression du fluide d'exploitation avec lesdits moyens (14) de mesure, par l'intermédiaire d'un second diaphragme (54) de mesure qui est raccordé uniquement au premier diaphragme d'exploitation avec

un seul côté exposé au liquide de remplissage ; et
i) mesurer ladite température du fluide d'exploitation au niveau desdits moyens (14) de mesure qui varient avec des changements de ladite température.

10. Procédé selon la revendication 9, dans lequel l'étape de mesurer ladite température de fluide d'exploitation est réalisée au niveau desdits moyens (14) de mesure par ledit premier diaphragme (52) de mesure qui varie avec les changements de ladite température,

11. Procédé selon la revendication 9, dans lequel l'étape de mesurer ladite température de fluide d'exploitation est réalisée au niveau des moyens (14) de mesure par ledit second diaphragme (54) de mesure qui varient avec les changements de ladite température.

12. Procédé selon la revendication 9, dans lequel l'étape de mesurer ladite température de fluide d'exploitation est réalisée au niveau des moyens (14) de mesure par un élément (106) de mesure de température qui varie avec des changements dans ladite température du fluide d'exploitation, ayant un seul côté soumis auxdits changements de température à partir dudit premier diaphragme (40) d'exploitation et espacé desdits premier et second diaphragmes (52,54) de mesure.

13. Procédé selon l'une quelconque des revendications 9 à 12, comportant en outre les étapes de :

a) calculer la vitesse d'écoulement, *Vf*, en temps que fonction de ladite fréquence desdits remous de pression en alternance telle que mesurée à partir desdits moyens (14) de mesure ;
b) déterminer la densité du fluide d'exploitation, en tant que fonction de ladite pression du fluide d'exploitation et de la température telle que déterminée à partir des moyens (14) de mesure ; et
c) calculer le taux d'écoulement massique, MFR, à partir de la relation :

$$\mathrm{MFR} = d{*}\alpha{*}Yf$$

où *D* est ladite densité du fluide d'exploitation et α est l'aire de la section transversale du tube d'écoulement.

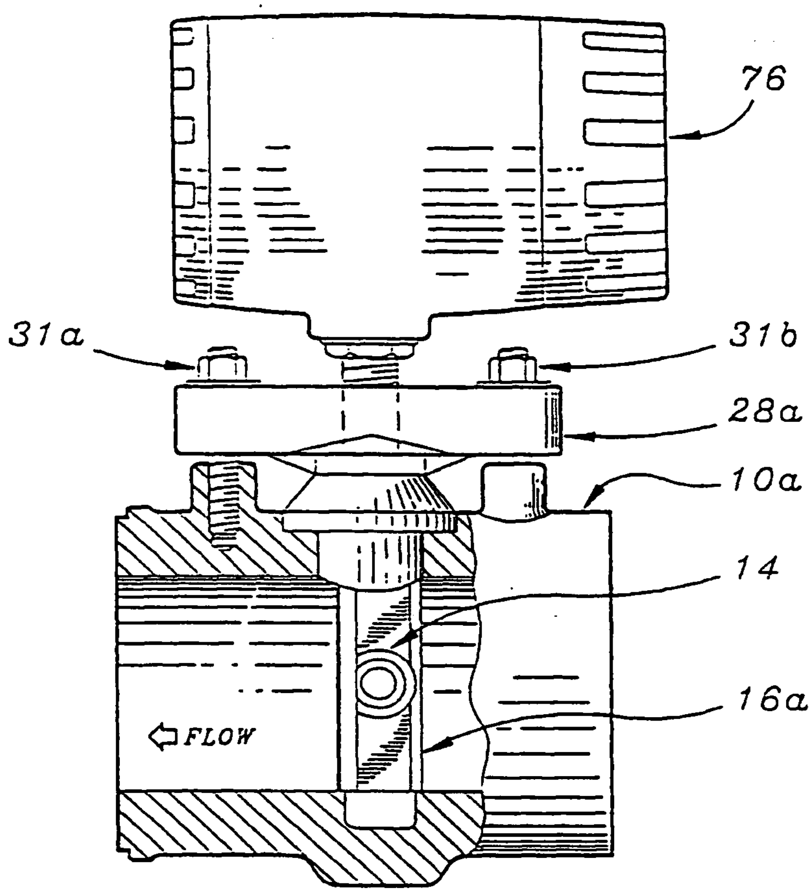


Fig. 1

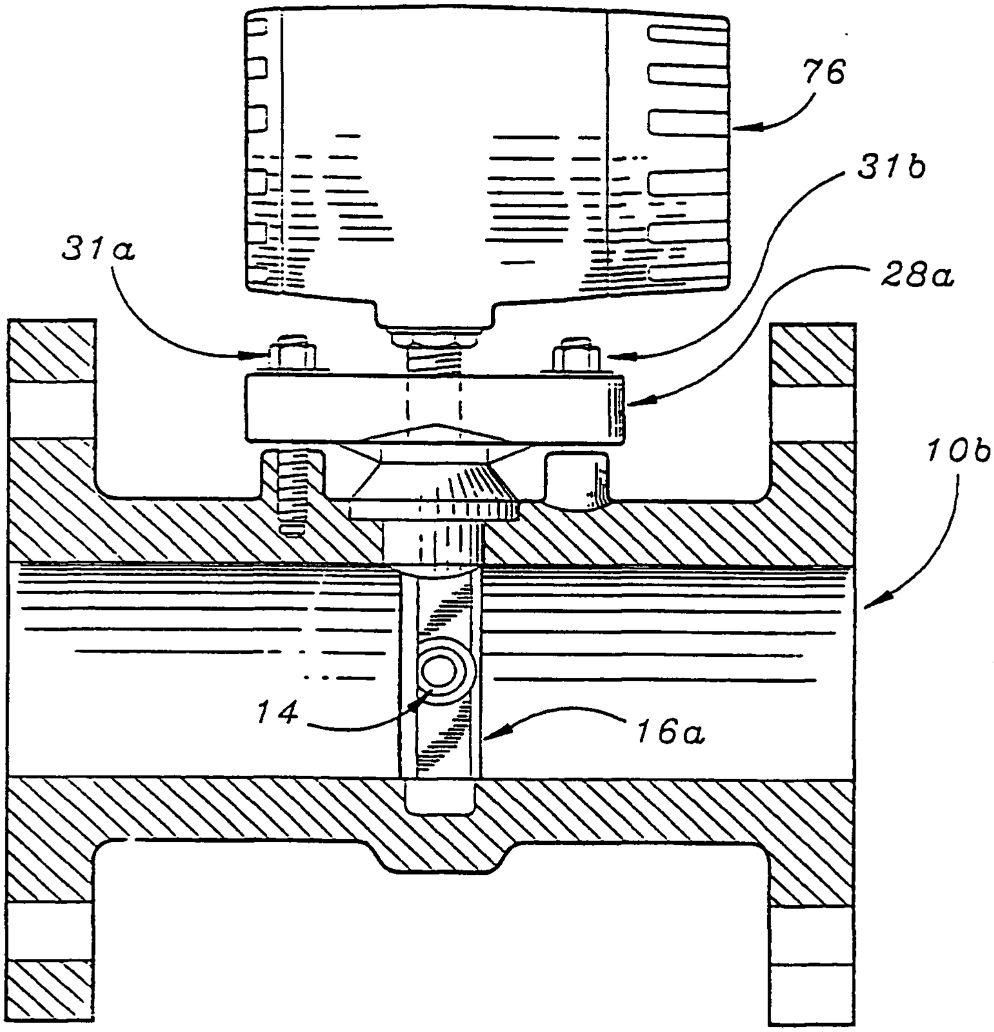


Fig. 2

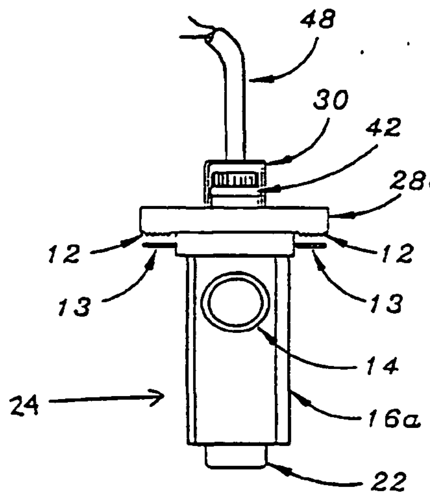
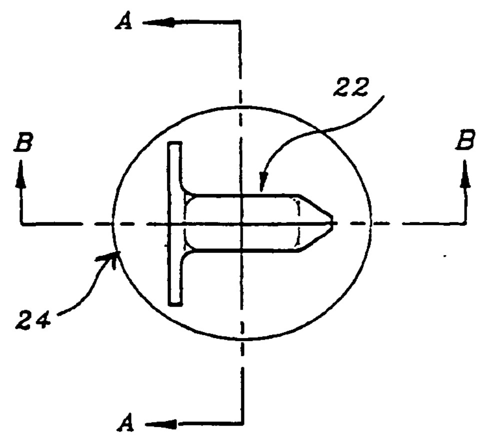


Fig. 3



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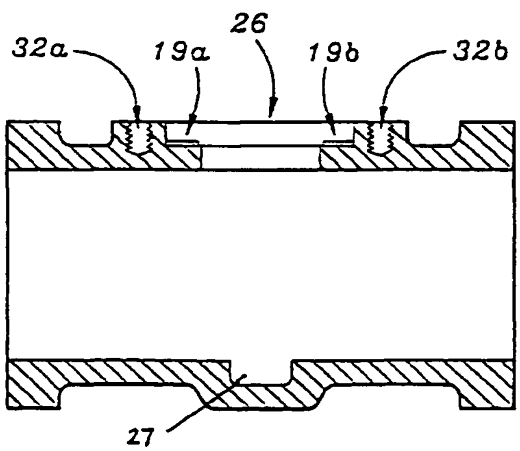


Fig. 5

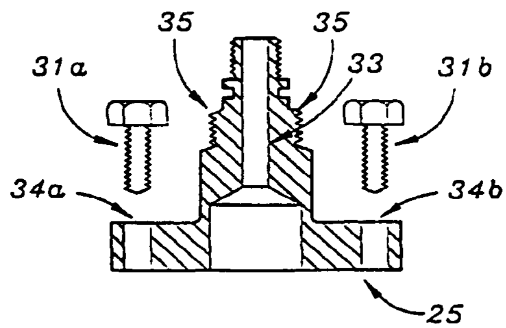


Fig. 6

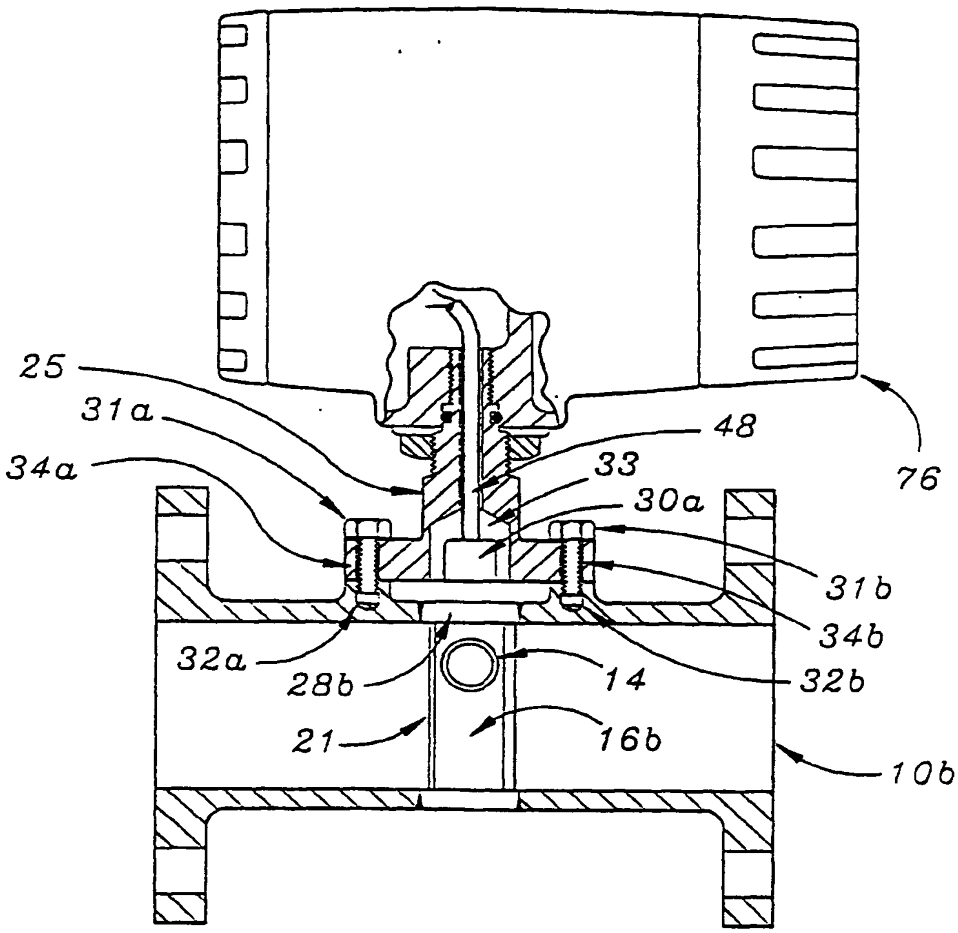


Fig. 7

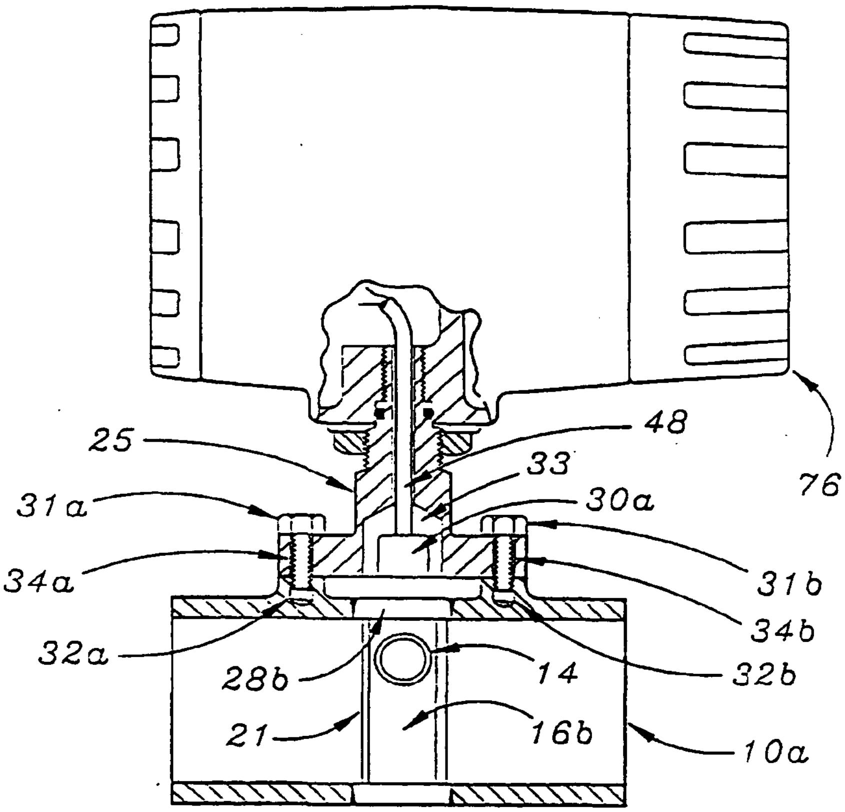


Fig. 8

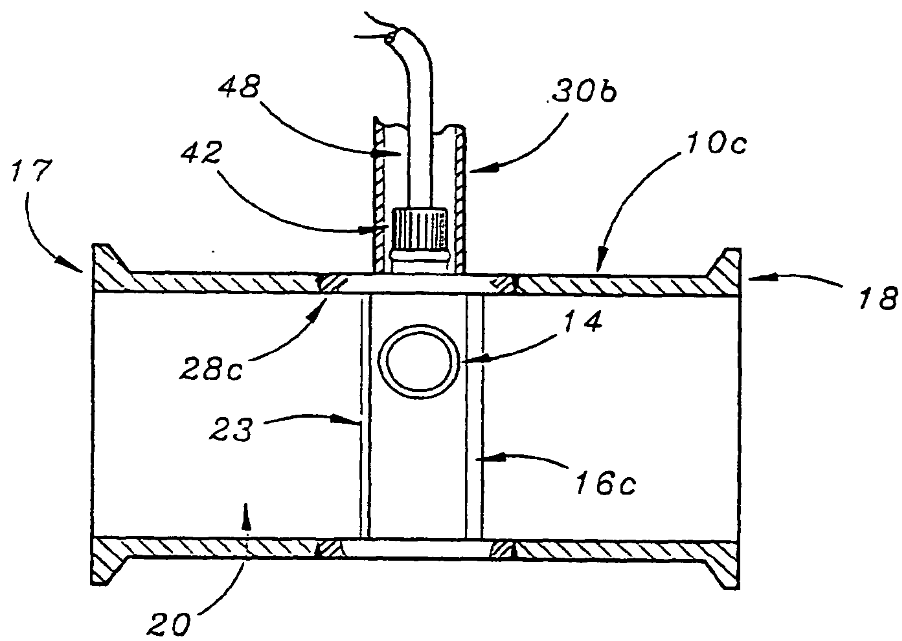


Fig. 9

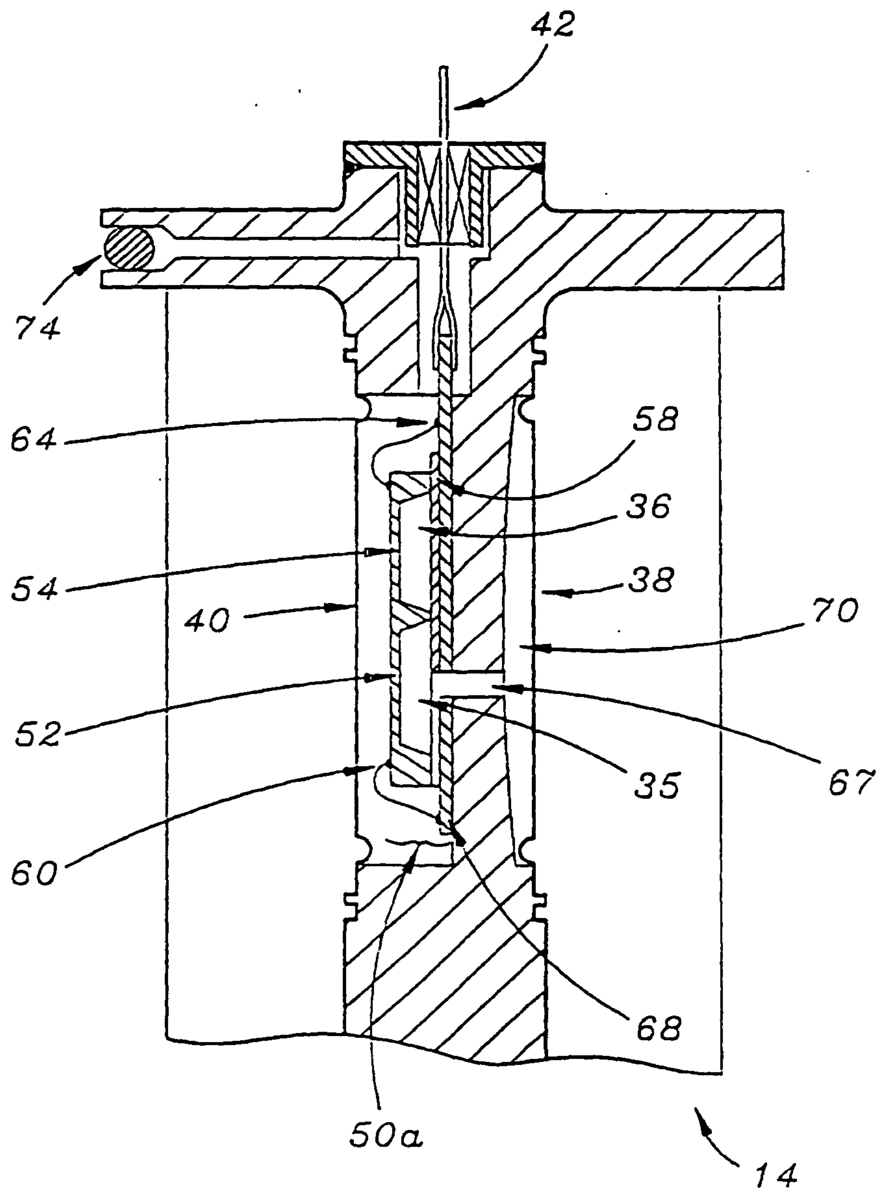


Fig. 10

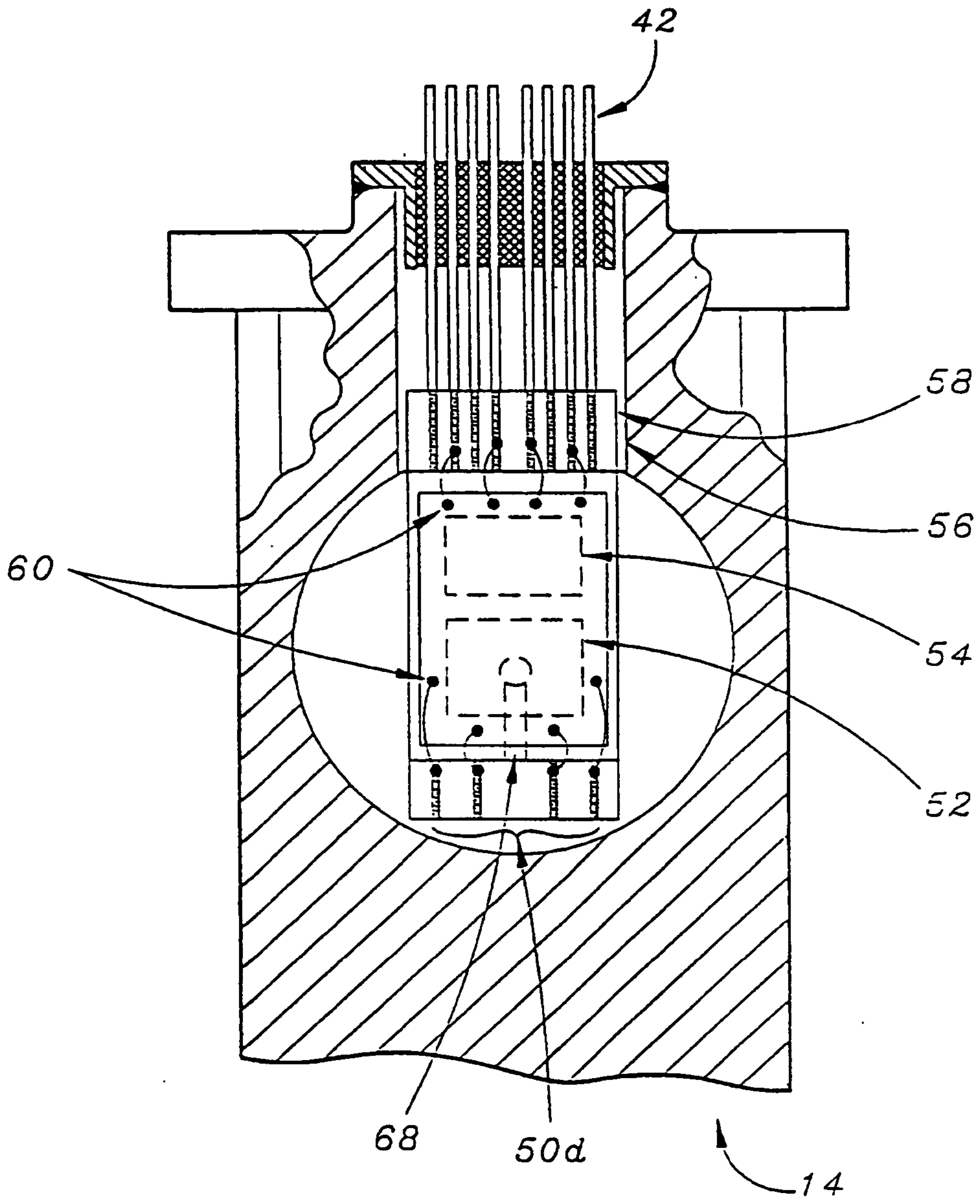


Fig. 11

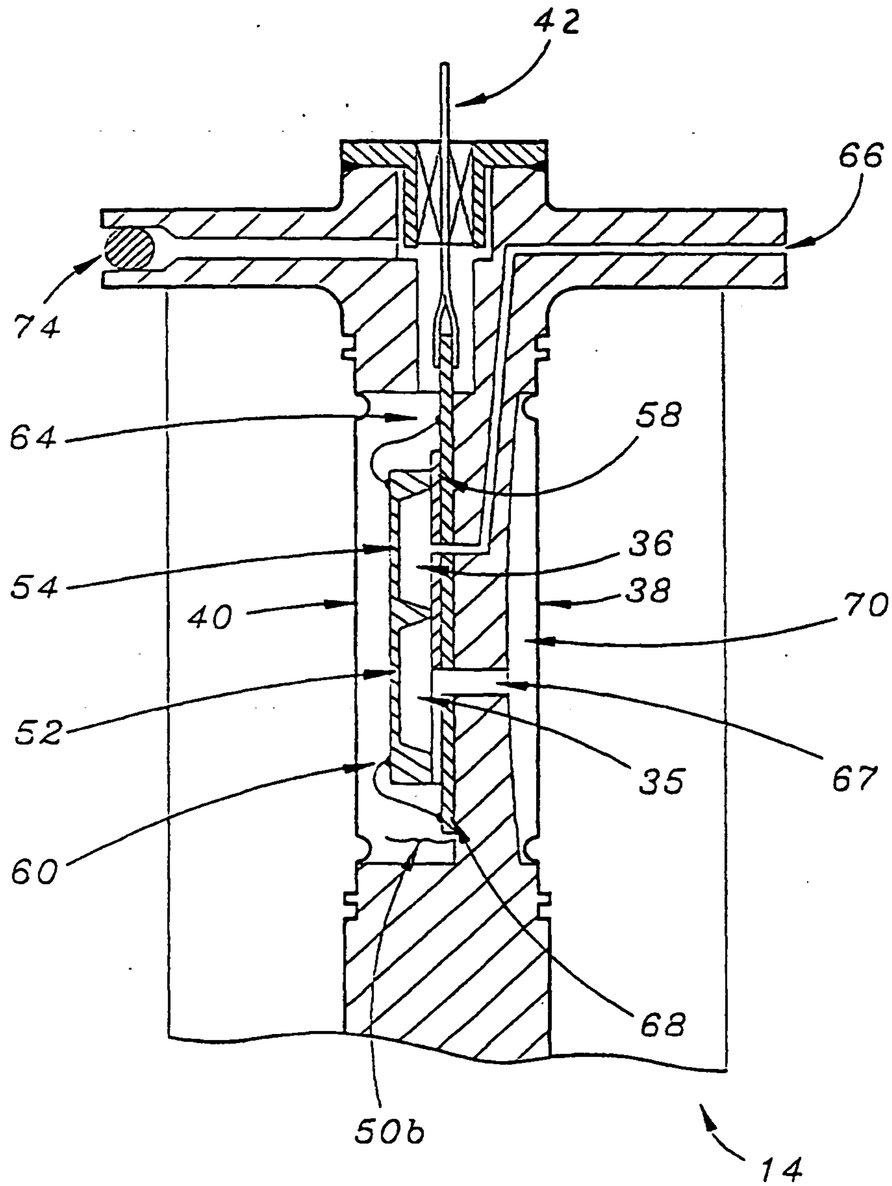
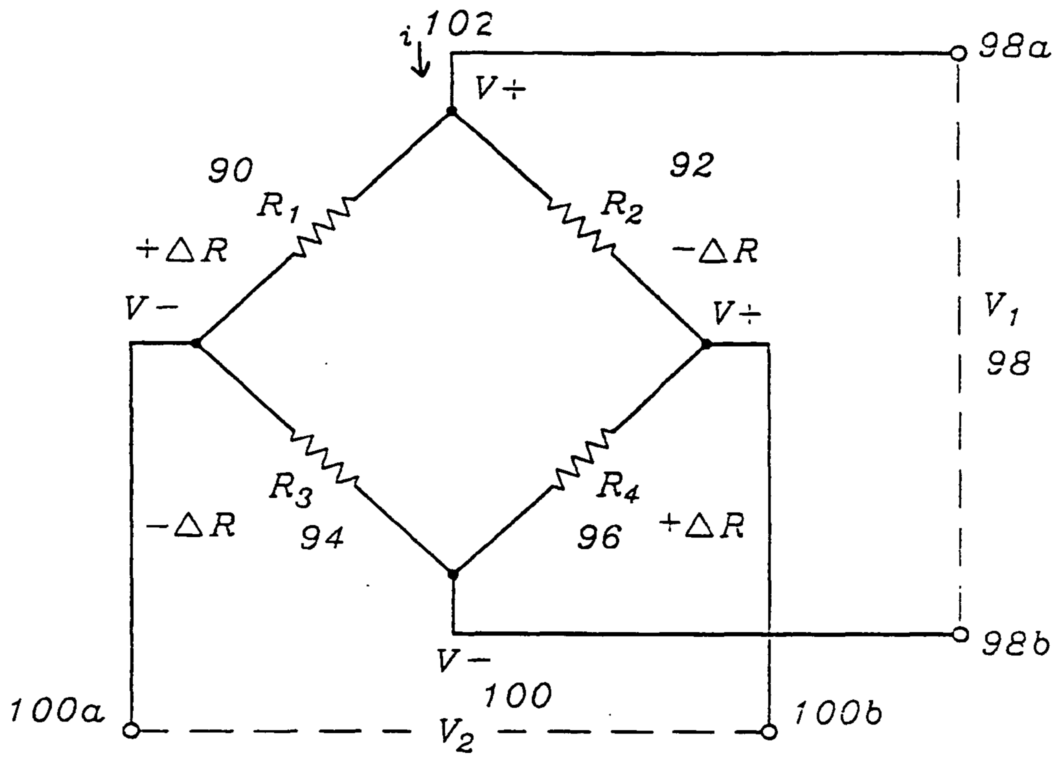


Fig. 12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R_2
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V+
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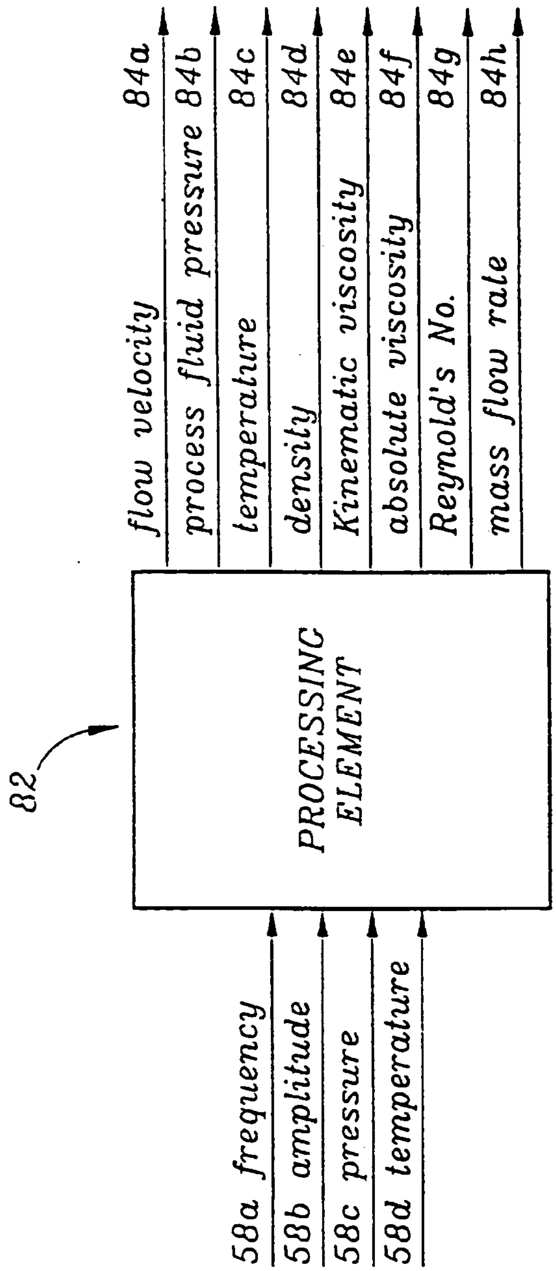
94
96
+ΔR
V−
98b
100
100a
100b
V_2

Fig. 13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process fluid pressure 84b
temperature 84c
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Kinematic viscosity 84e
absolute viscosity 84f
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mass flow rale 84h
PROCESSING ELEMENT
82
58a frequency
58b amplitude
58c pressure
58d temperature

Fig. 14

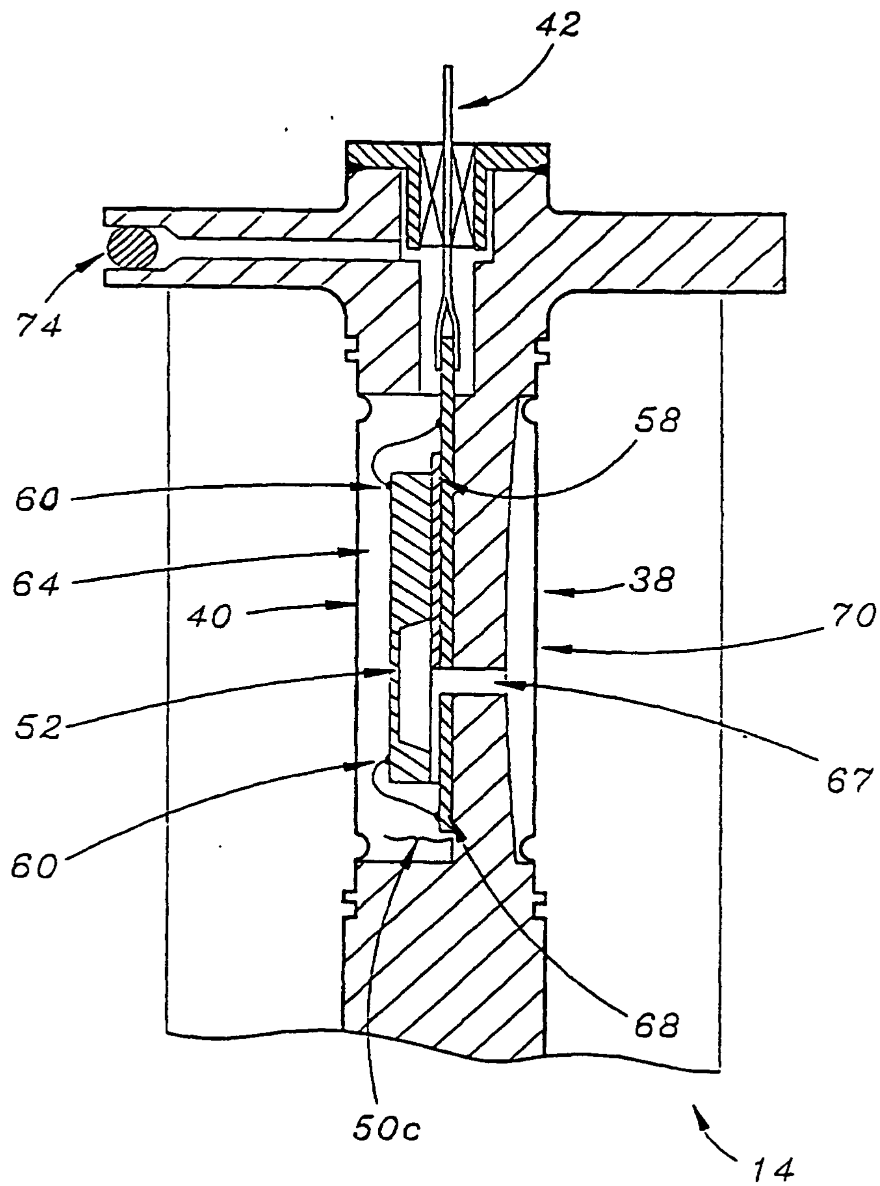

Fig. 15

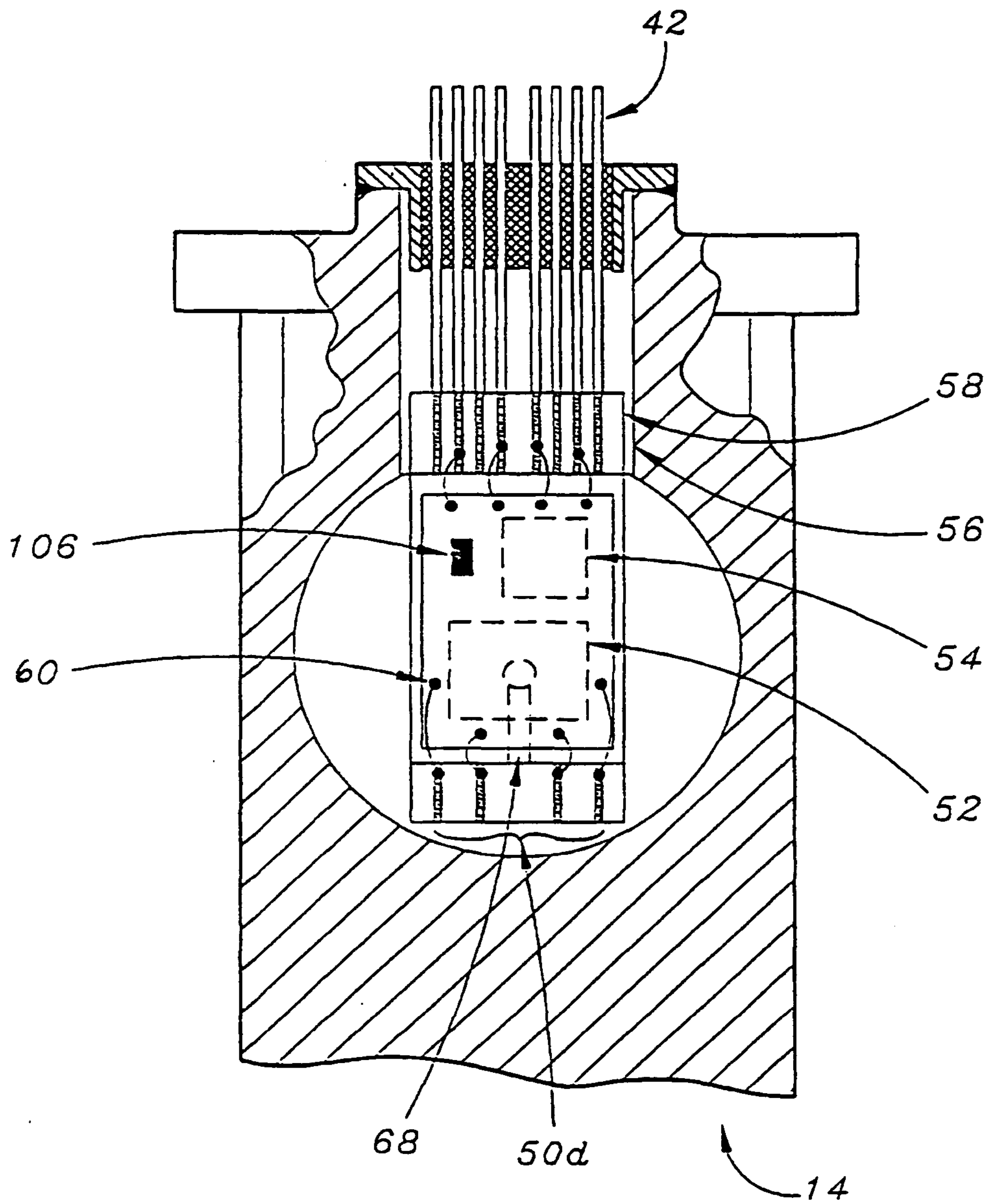

Fig. 16

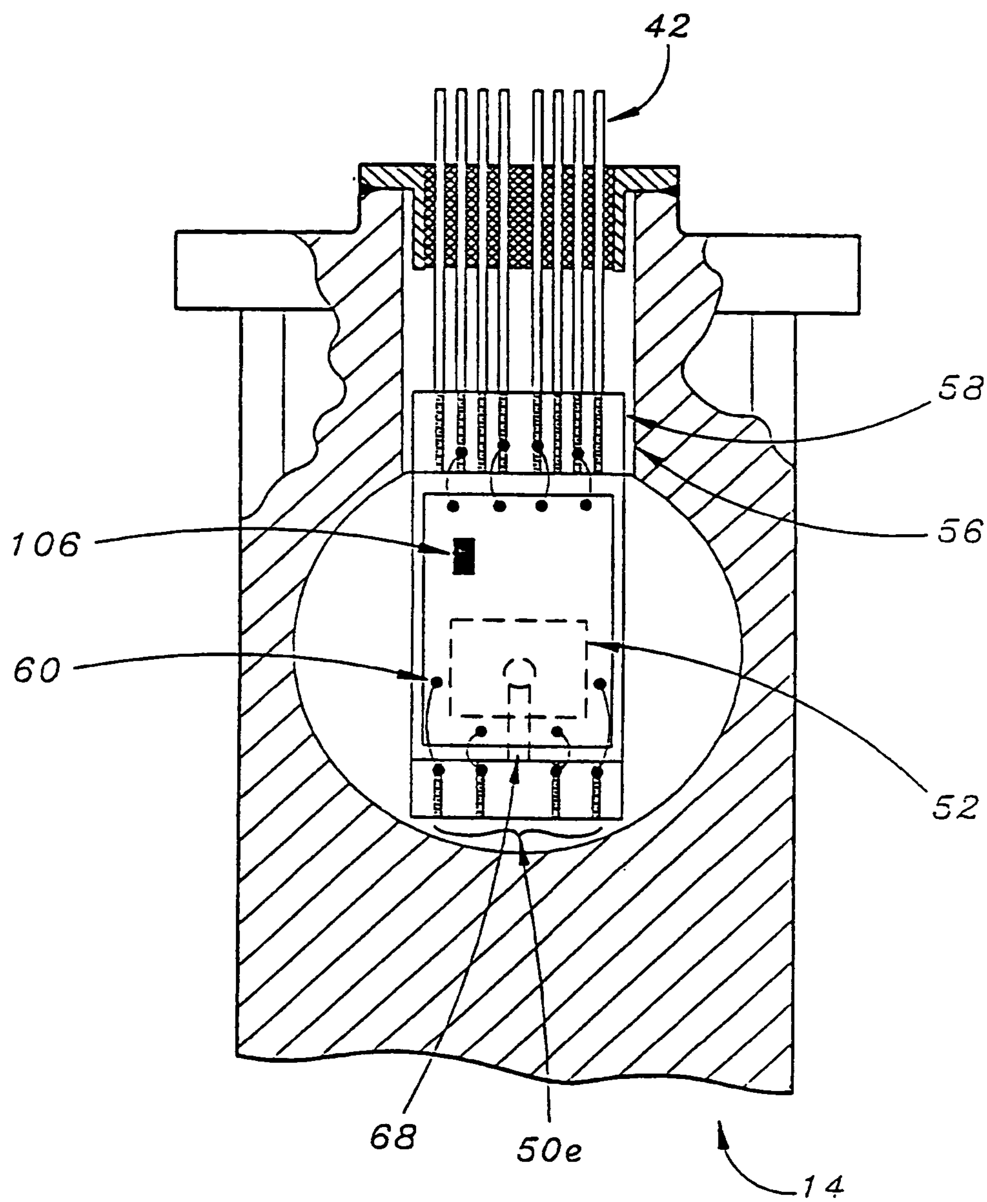

Fig. 17

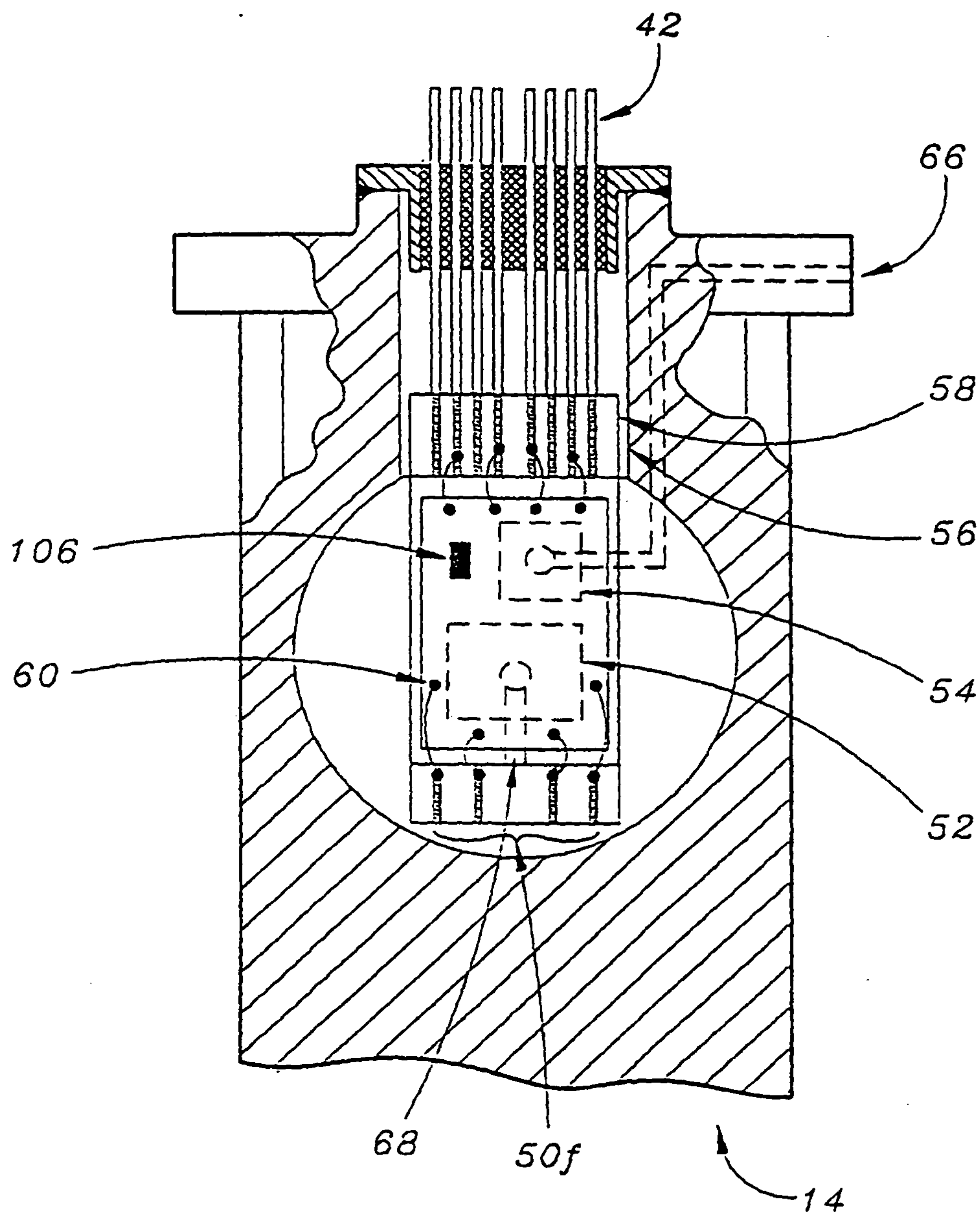

Fig. 18

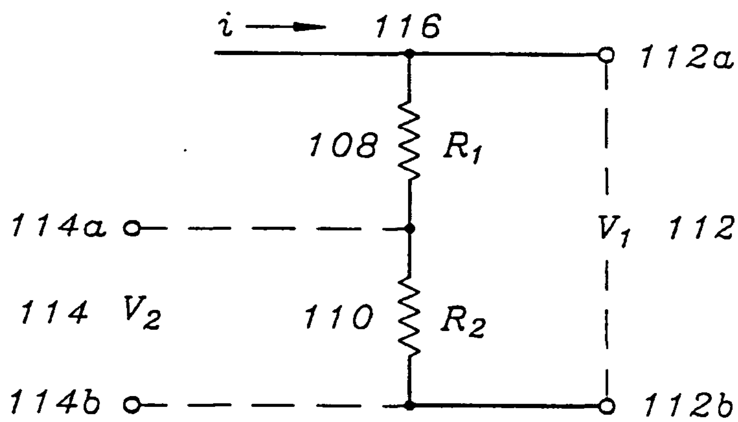

Fig. 19